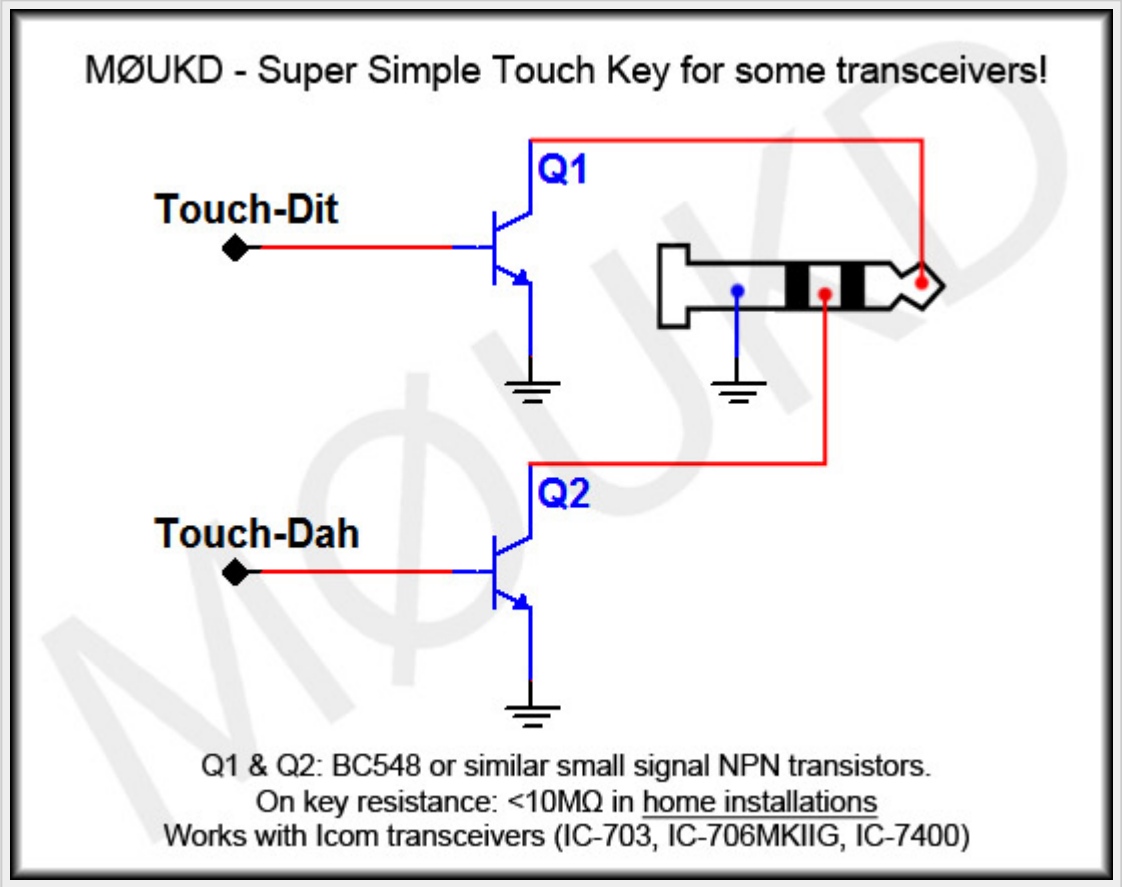
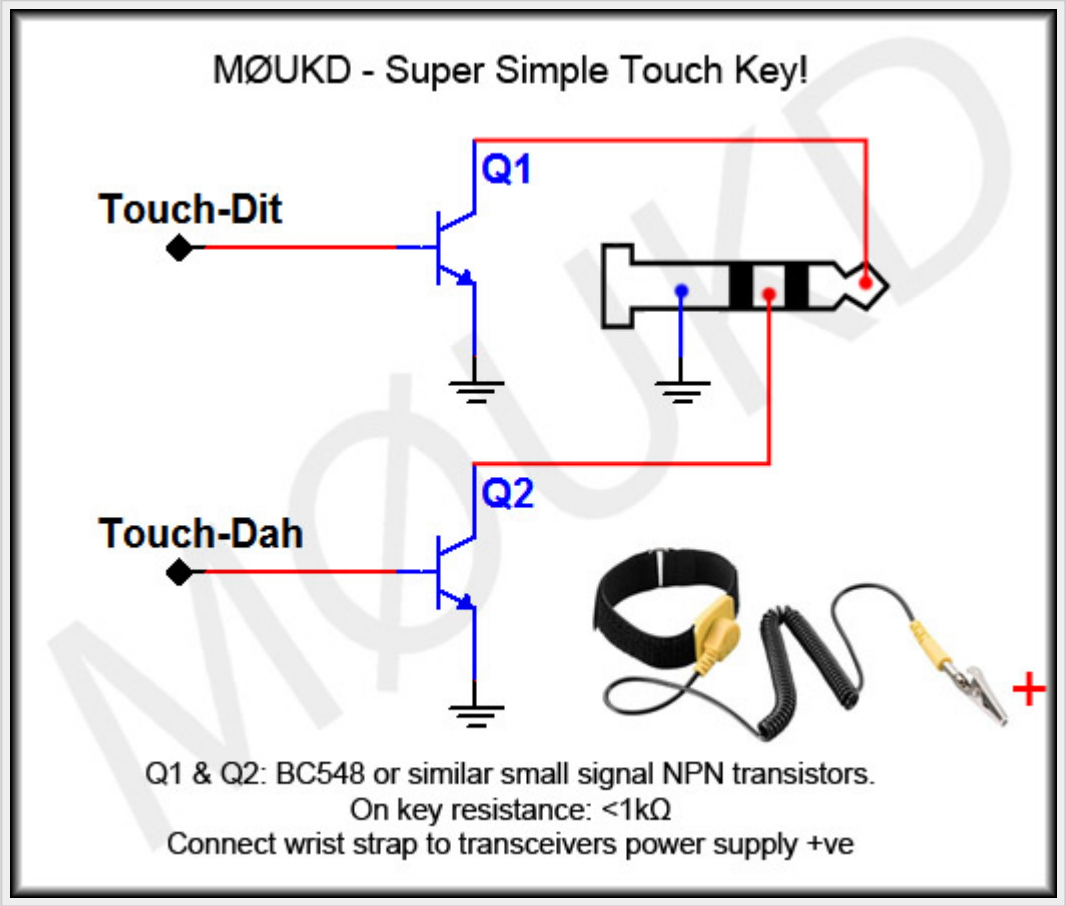
Simple CW Touch Keyer Circuits

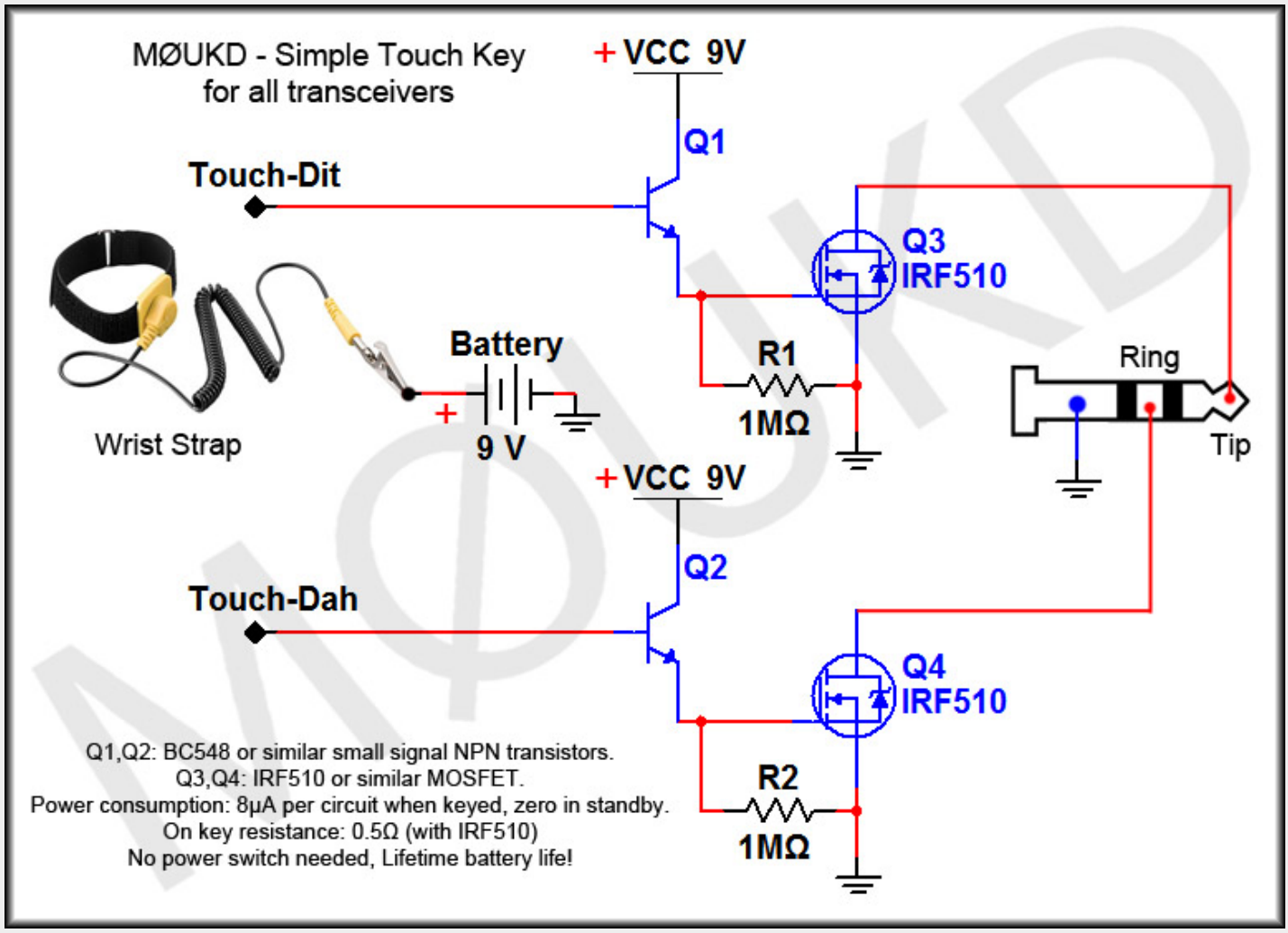
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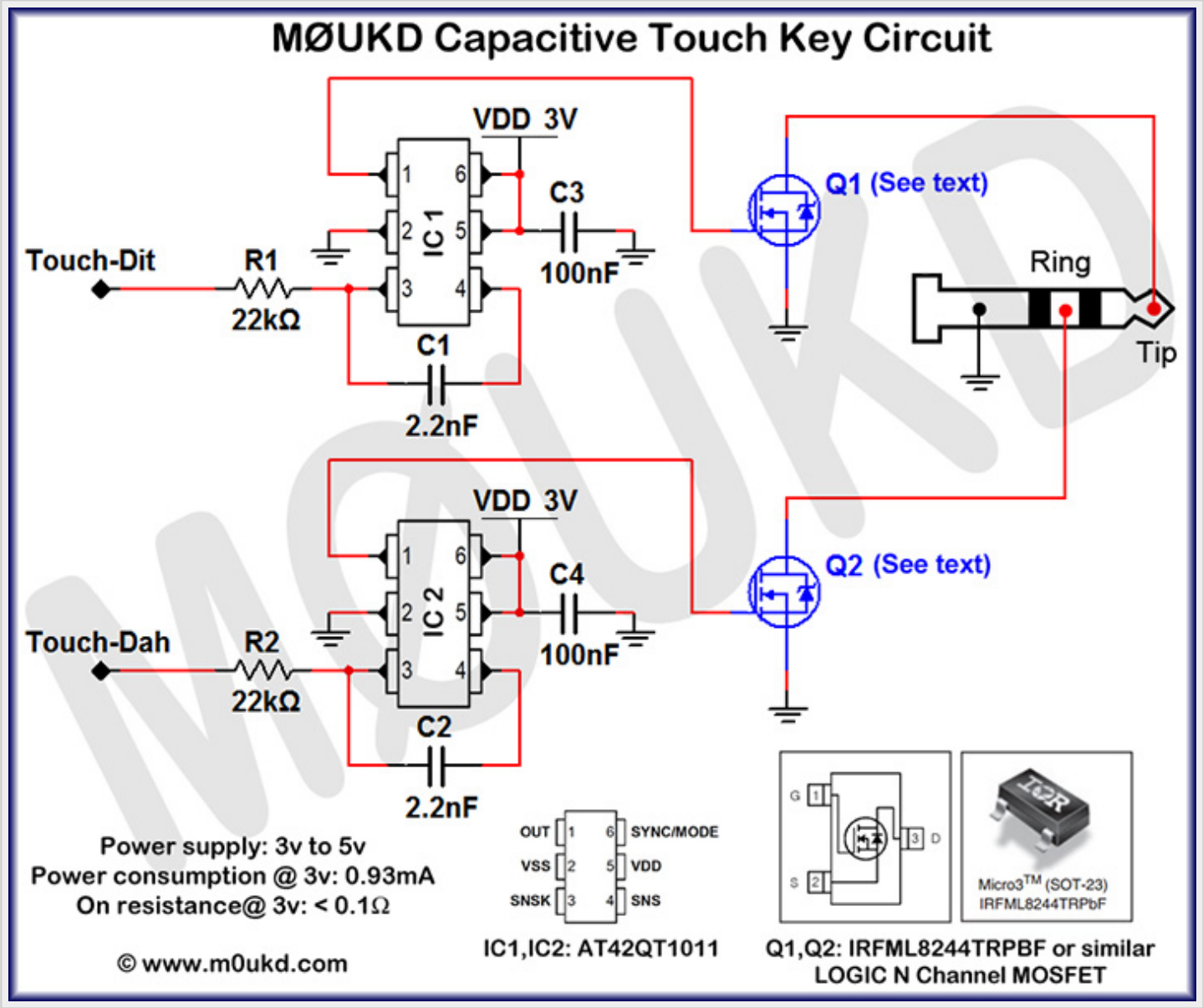
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Home

Miscellaneous Items



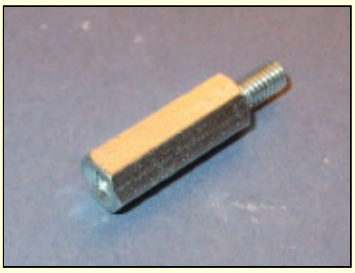
SOLID BRASS SPACER 25mm x 10mm x M4. This is tapped both ends.

P/N
05-002
£ POA



BLACK NYLON SPACER This is 2 inch or 50mm long and 1/2 inch or 12.5mm diameter. There is a threaded M4 hole either end for screw fixing. It is ideal for mounting component boards. Larger View.

P/N
05-005
£ POA



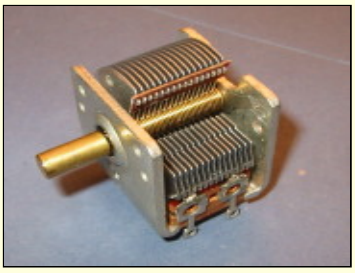
ZINC PLATE HEX SPACER 25mm x 8mm x M4

P/N
06-004
£ POA



TURRET TAG

P/N
13-001
£ POA



TUNING CAPACITOR 15-365pF. This is new manufacture. Supplied with two fixing screws. Shaft size is 1/4 inch Dia x 7/8 inch long. Larger View.

P/N
21-001
£ POA

SLOW MOTION DRIVE 36-1 plus 6-1. This is a superb slow

P/N



motion ball drive containing both 36-1 ratio slow motion and 6-1 on the same drive. Turn the dial clockwise for 6-1 and anticlockwise for 36-1. This is the flange type for mounting my dial plates directly. Larger View.

25-001
£ POA



SLOW MOTION DRIVE 6-1 This is a single acting drive with Flange for mounting my Dial Plates. *Jackson Brothers* type drive. Larger View.

P/N
25-002
£ POA



BLACK NYLON HEX PILLAR This is 1 inch or 25mm long and 3/8 or 10mm fiameter. Hole size is M5. This has solid brass threaded stud on one end plus threaded nylon hole other end. Suitable for insulating coils or for circuit board mounting. Larger View.

P/N
25-004
£ POA



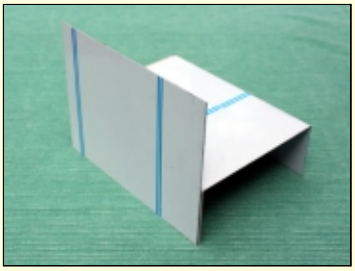
CHICKEN HEAD POINTER KNOB This black plastic pointer knob has remained the same design since the 1930's. It is a very authentic looking knob for the crystal sets. Larger View.

P/N
23-001
£ POA



BLACK TAPERED FOOT This adds the final touch to your projects. It is made from hard plastic and is fixed by screwing to base. 15mm long x12mm diameter. M4 hole fixing. Larger View.

P/N
24-001
£ POA



ALUMINIUM CHASSIS This simple chassis is suitable for Crystal and Regen Radios plus many small electronic projects. The front panel is 8 x 6 inches (200x150mm approx)made from 18Gauge (1.2mm) Polycoated Aluminium. The Chassis section is 8x6x2.5 inches and made from 20 Gauge (.75mm) Polycoated Aluminium Larger View.

P/N
40-001
£ POA

Home

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DIY Audio Home

Tube Microphone Preamp

A while back a friend that does some home recording asked me about a tube microphone preamp. Something I hadn't designed yet... so I designed one.

This particular design is pretty high-end. I started with the best microphone input transformer I could find (at least without having something custom made). So this is *not* an inexpensive preamp... the input transformer alone sells for $135! The total cost for everything including the case and PCB is right around $400.

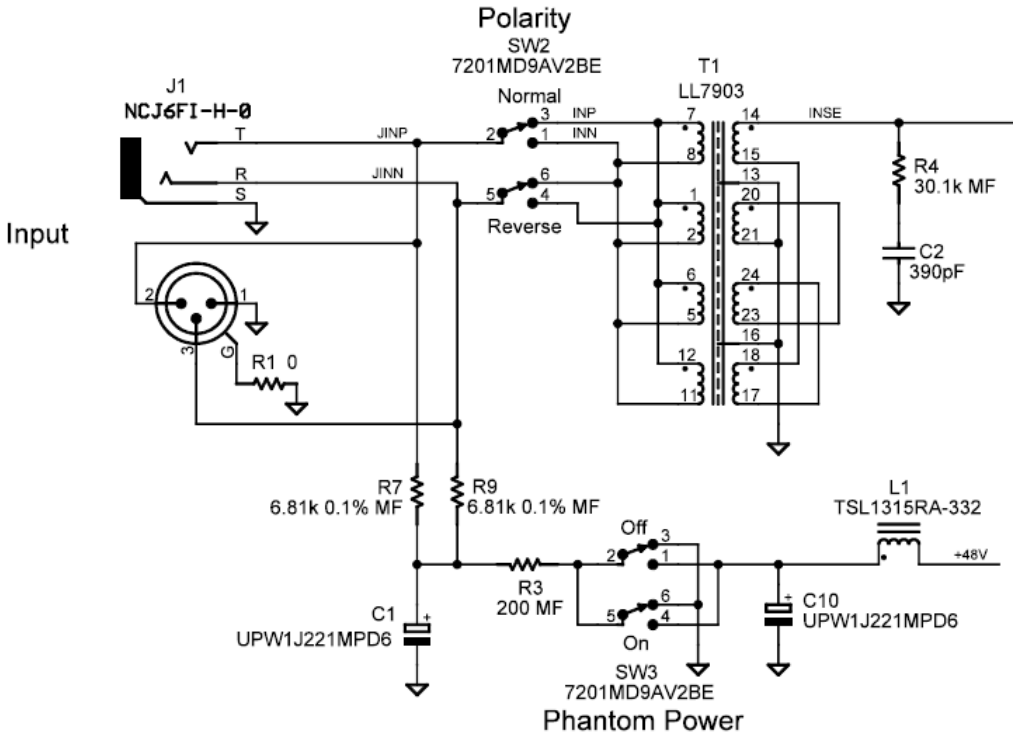
I'm selling the PCBs for $30 each on eBay.

The Circuit

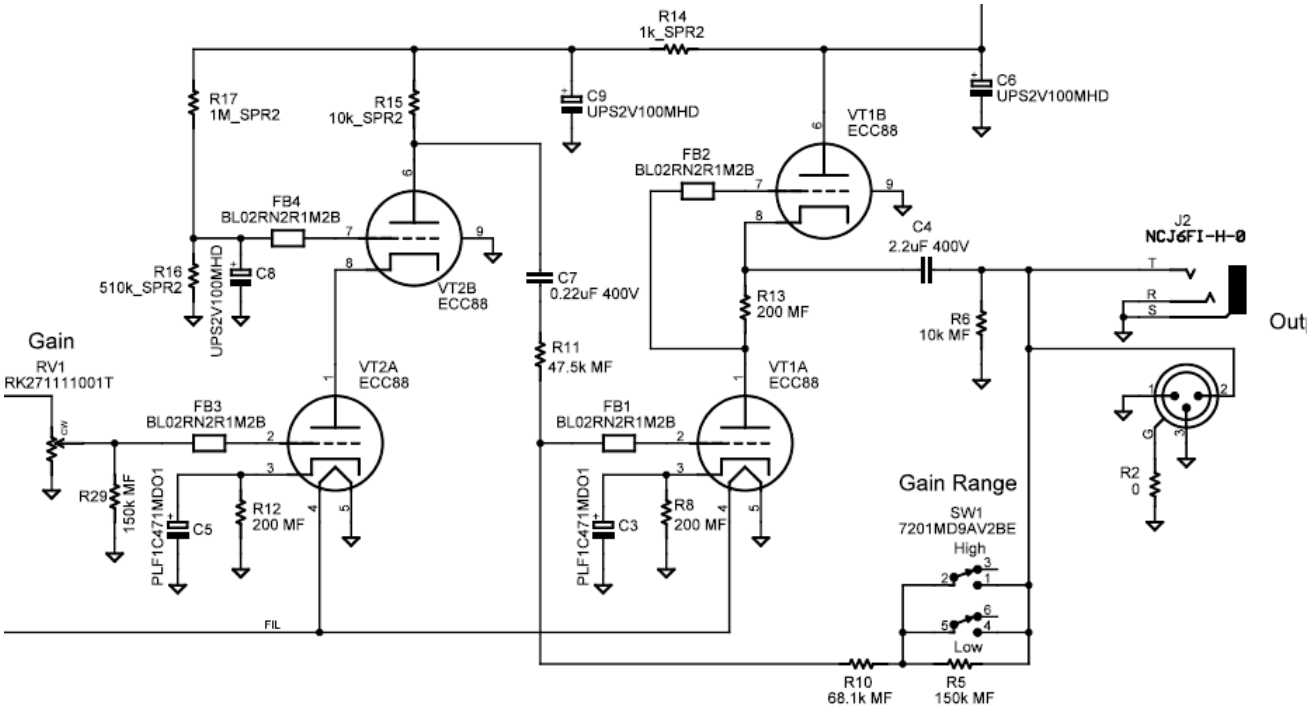
The circuit topology uses an input transformer, followed by a 6922/6DJ8/ECC88 cascode stage. The output uses another ECC88, in SRPP, with some feedback around it. The feedback has two settings, giving two gain selections.

Click here for a full PDF schematic. You can download the BOM either in PDF or XLS format.

Input is via a Neutrik combo 1/4"/XLR jack. The signal passes through a Lundahl LL7903 transformer. Provisions for phantom power as well as a polarity flip switch is included.

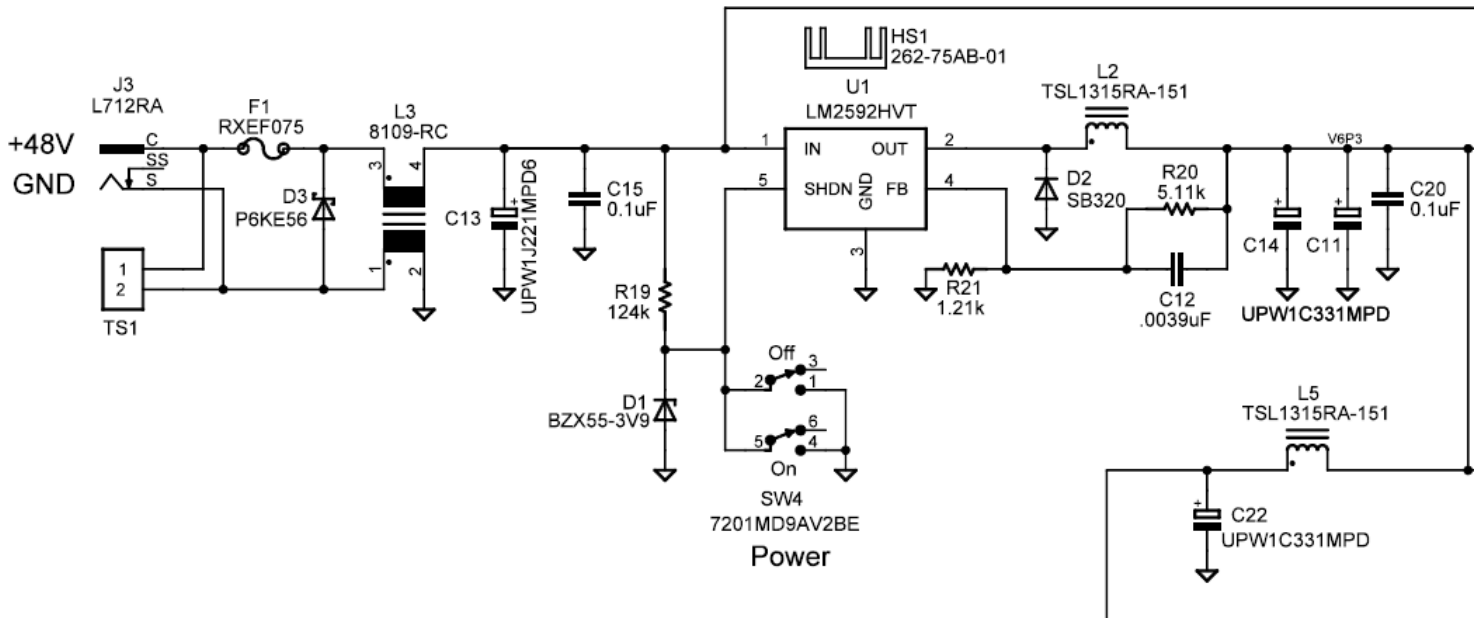


The amp stage proper: Cascode followed by SRPP. I know some people hate SRPP - it's too trendy, I guess. But here is seems to me the best choice, able to drive a 600 ohm load. Note some NFB around the final stage, two different amounts selected by a switch. The output - unbalanced, no output transformer - is supplied via another 1/4"/XLR combo jack. Yes, the XLR is the wrong sex, but you can't get a male combo jack, and front panel space was limited.

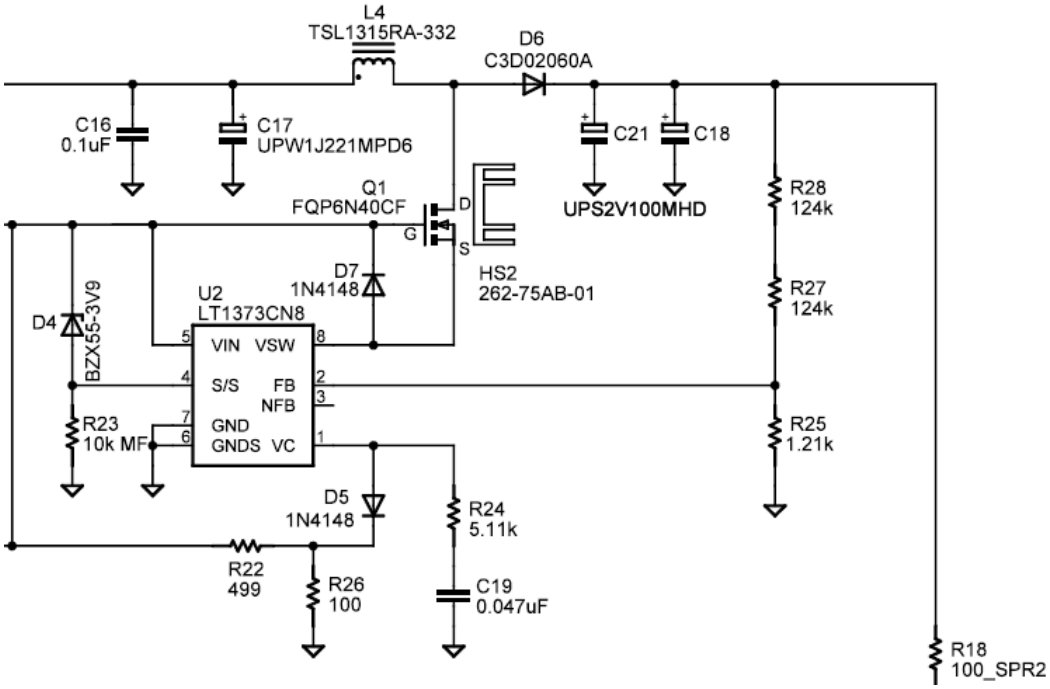


The power supply is, uh, unconventional. What? Who? Me? Yup. A switching supply, generating 6.3V filament voltage and +200V B+ from a 48VDC input. The beauty of switching supplies is that the noise they generate - and yes, they do generate some noise - is at high enough frequency that it's easy to filter, and above the audible range. For a low-level preamp like this I'd rather have a few millivolts of 100kHz than a few millivolts of 60Hz!

Here's the input and filament buck:



...and here's the B+ boost:



I powered this from a desktop-type switching 48V 1A power supply.

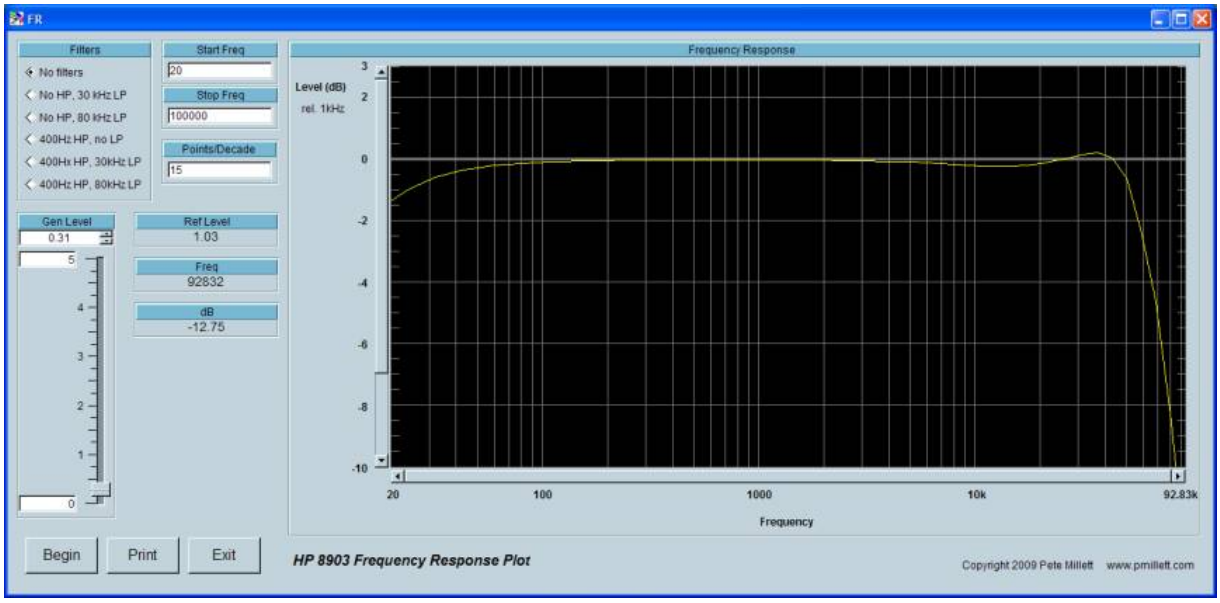
Performance

Some measurements:

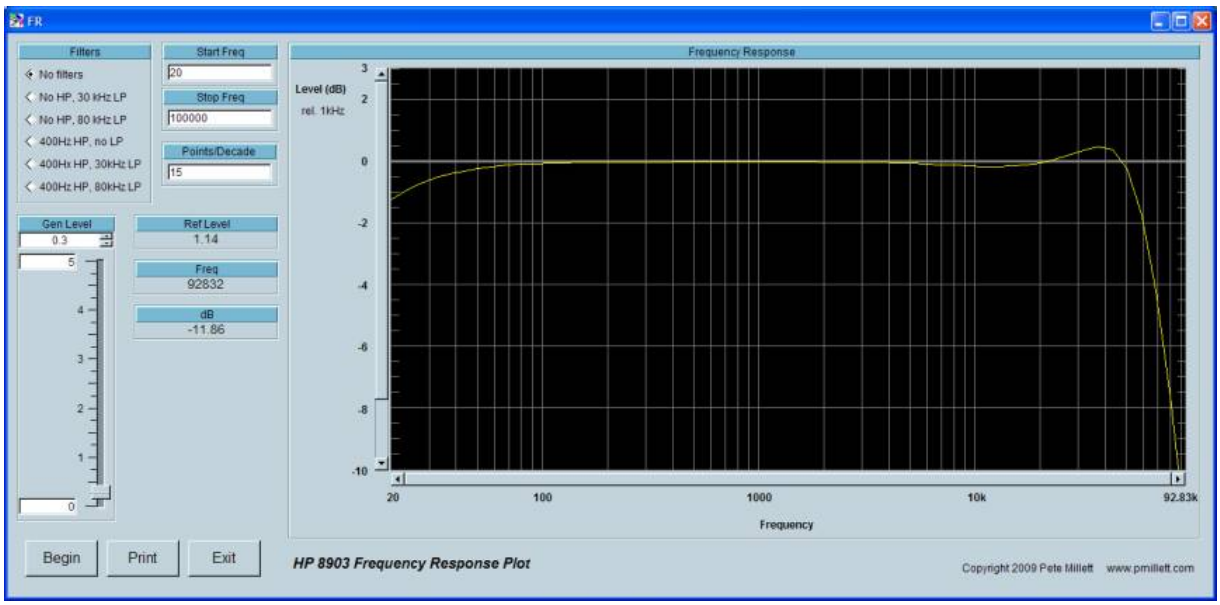
Parameter	***Gain setting***	***HiZ load***	***600 ohm load***
Maximum gain 10mV in 1kHz	Low	48dB	46dB
	High	58dB	55dB
Maximum output voltage 1kHz	Low	20V RMS	9V RMS
	High	42V RMS	9V RMS
THD+N 10mV in max gain	Low	0.6%	0.65%
	High	0.47%	0.5%
THD+N 10mV in 1V out 1kHz no LP filter	Low	0.25%	0.25%
	High	0.15%	0.15%
Freq Response 20Hz - 50kHz 10mV in 1V out	Low	+/-1.5dB	+/-2dB
	High	+/-1.5dB	+/-2.5dB

....and some graphs (all taken with a high-Z load):

Frequency response, low gain setting, 10mV in and 1V out:

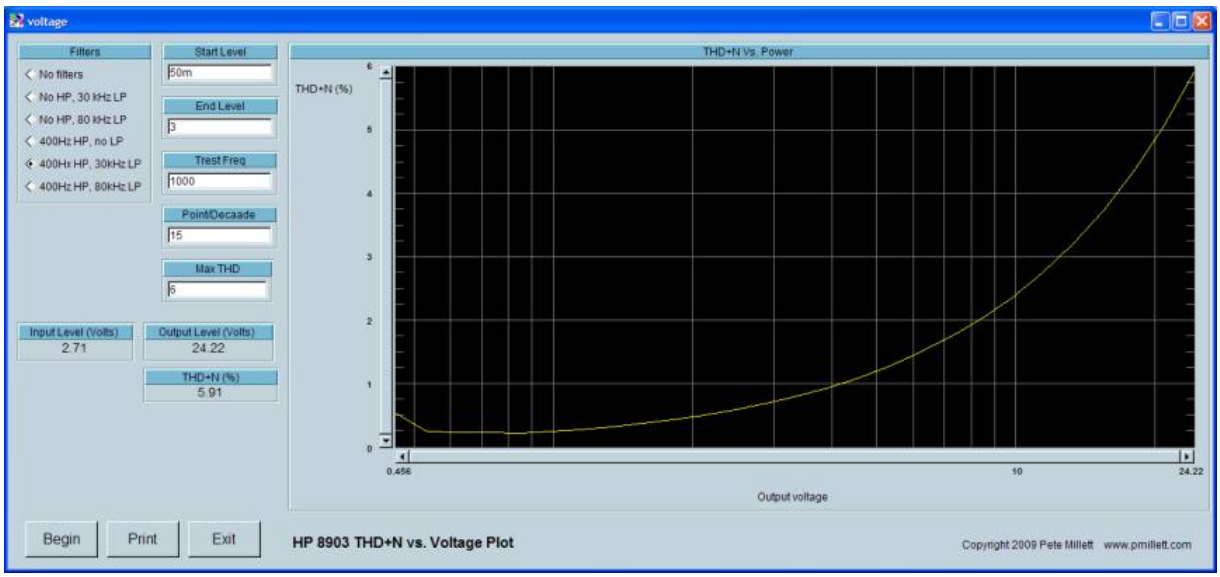


Same at high gain:

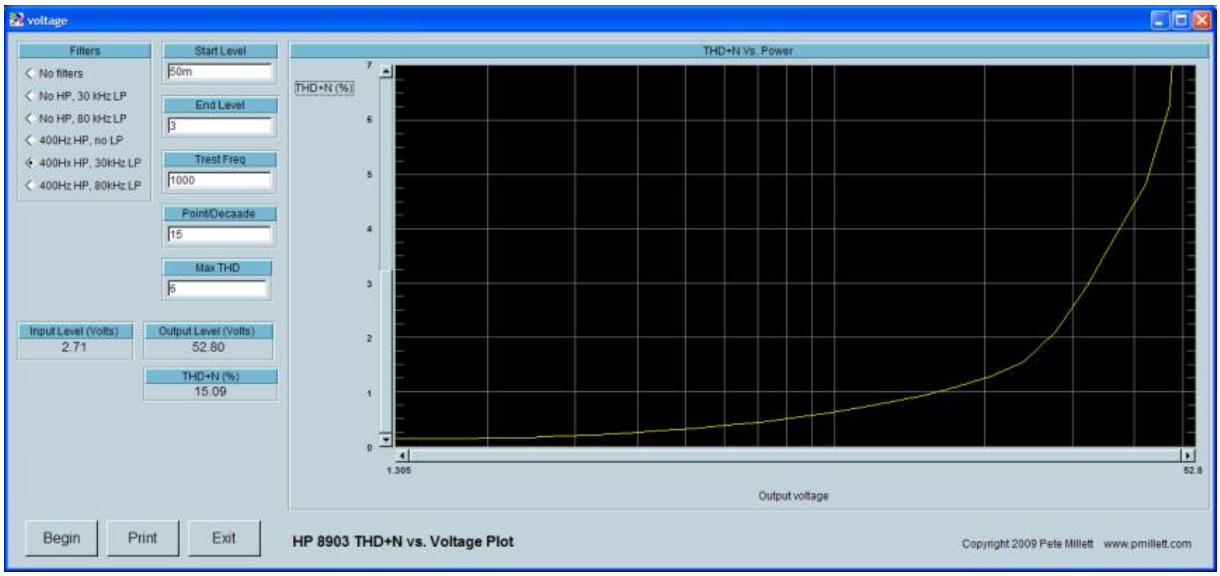


...the peaking at HF can be adjusted by changing the RC loading on the transformer secondary.

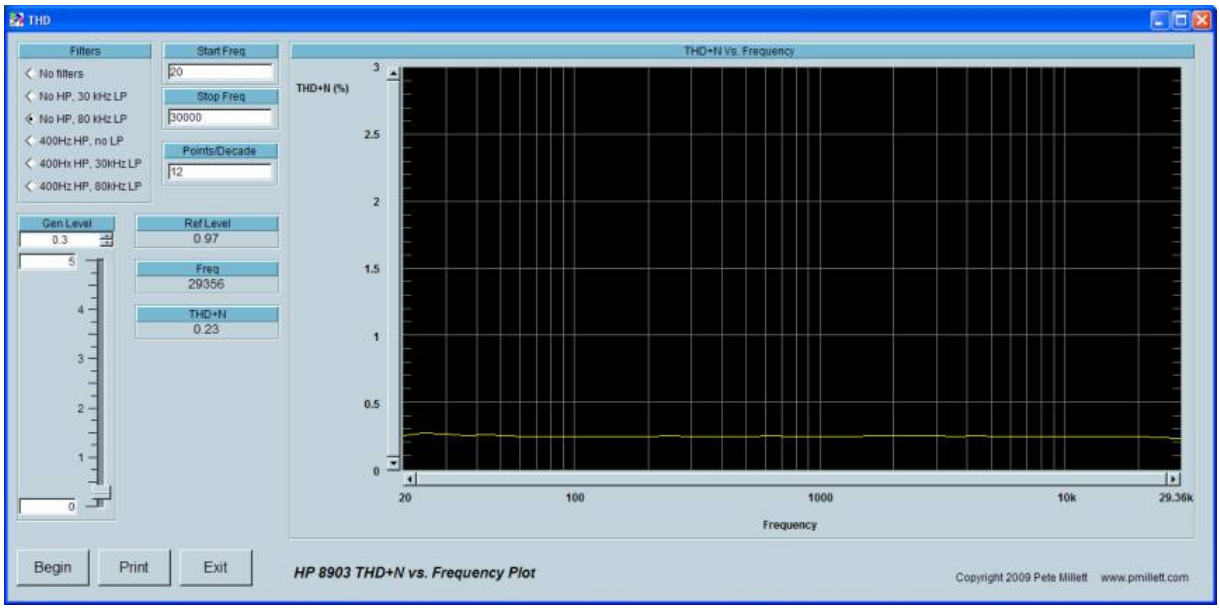
THD+N vs. output voltage, low gain setting:



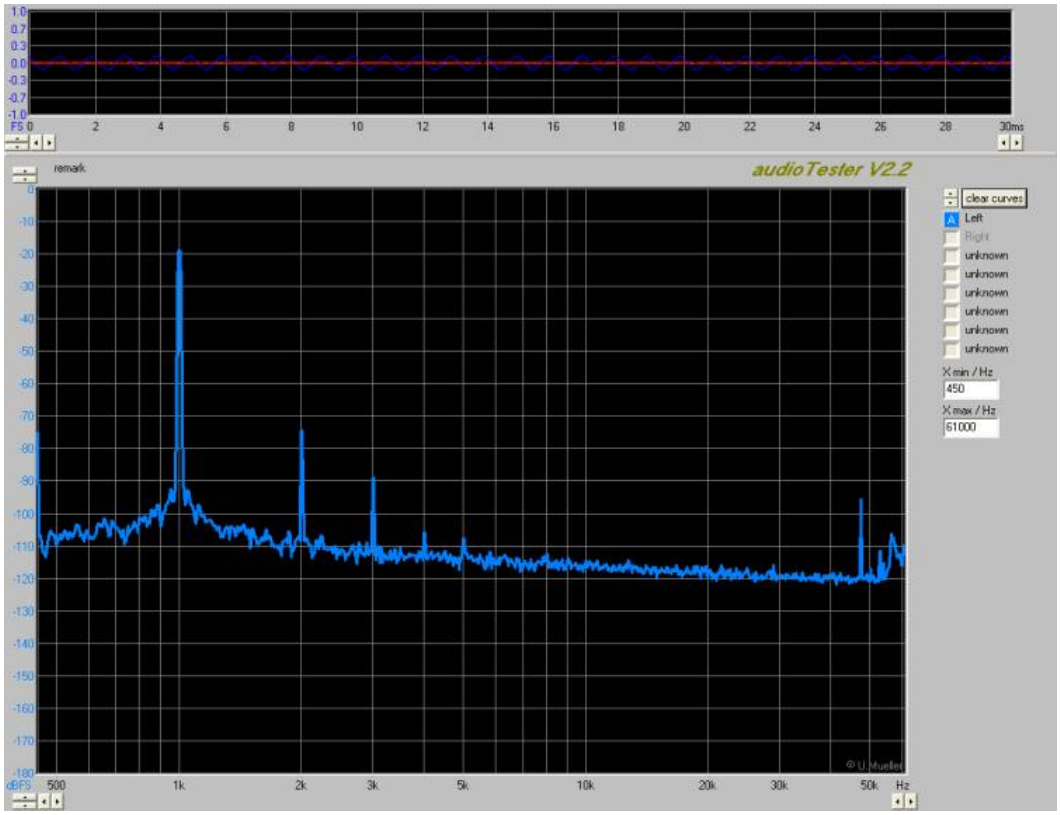
...and high gain:



THD+N vs. frequency, 10mV in 1V out, boring:



...and finally an FFT, 10mV in, 1V out:

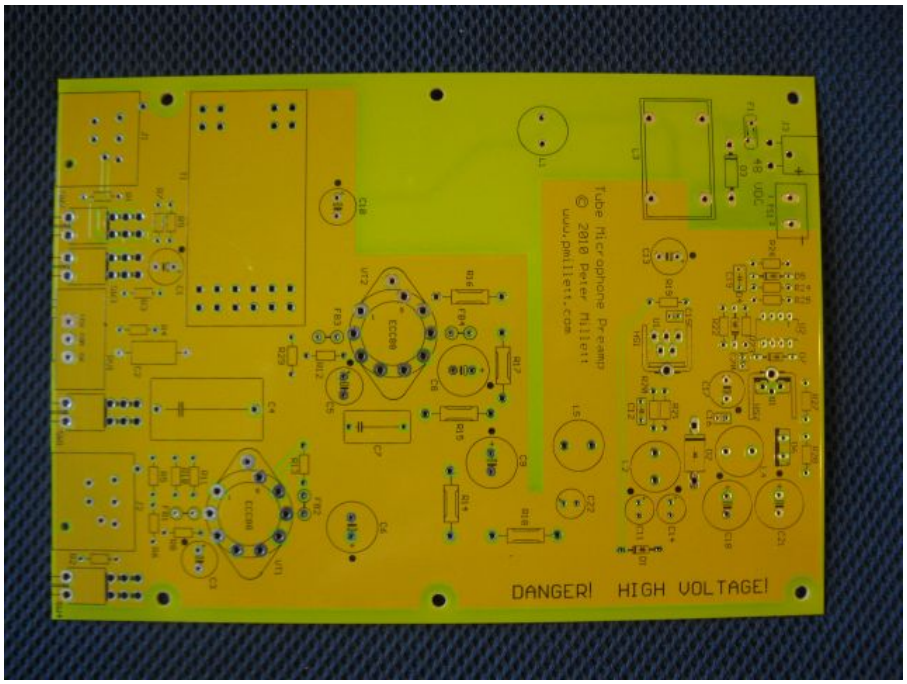


...nicely tubey!

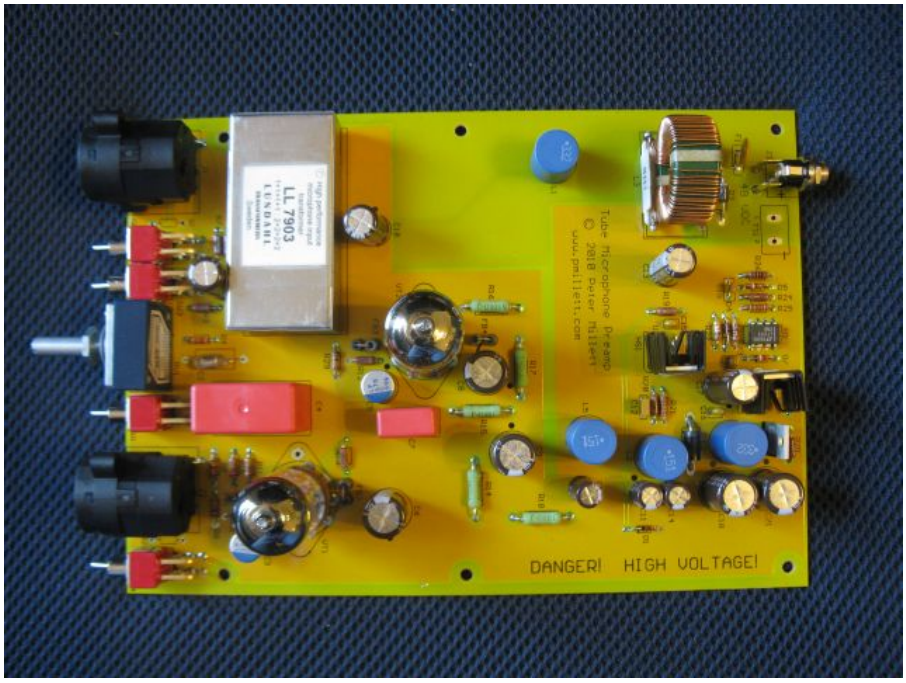
Implementation

I designed a PCB to contain the amp and fit inside an off-the-shelf enclosure.

Here's what the PCB looks like (click for a full-size image):



...and the assembled PCB:



The enclosure I put this in is an LMB-Heeger EAS-500 extruded box. I had front and rear panels made by Front Panel Express to fit the box.

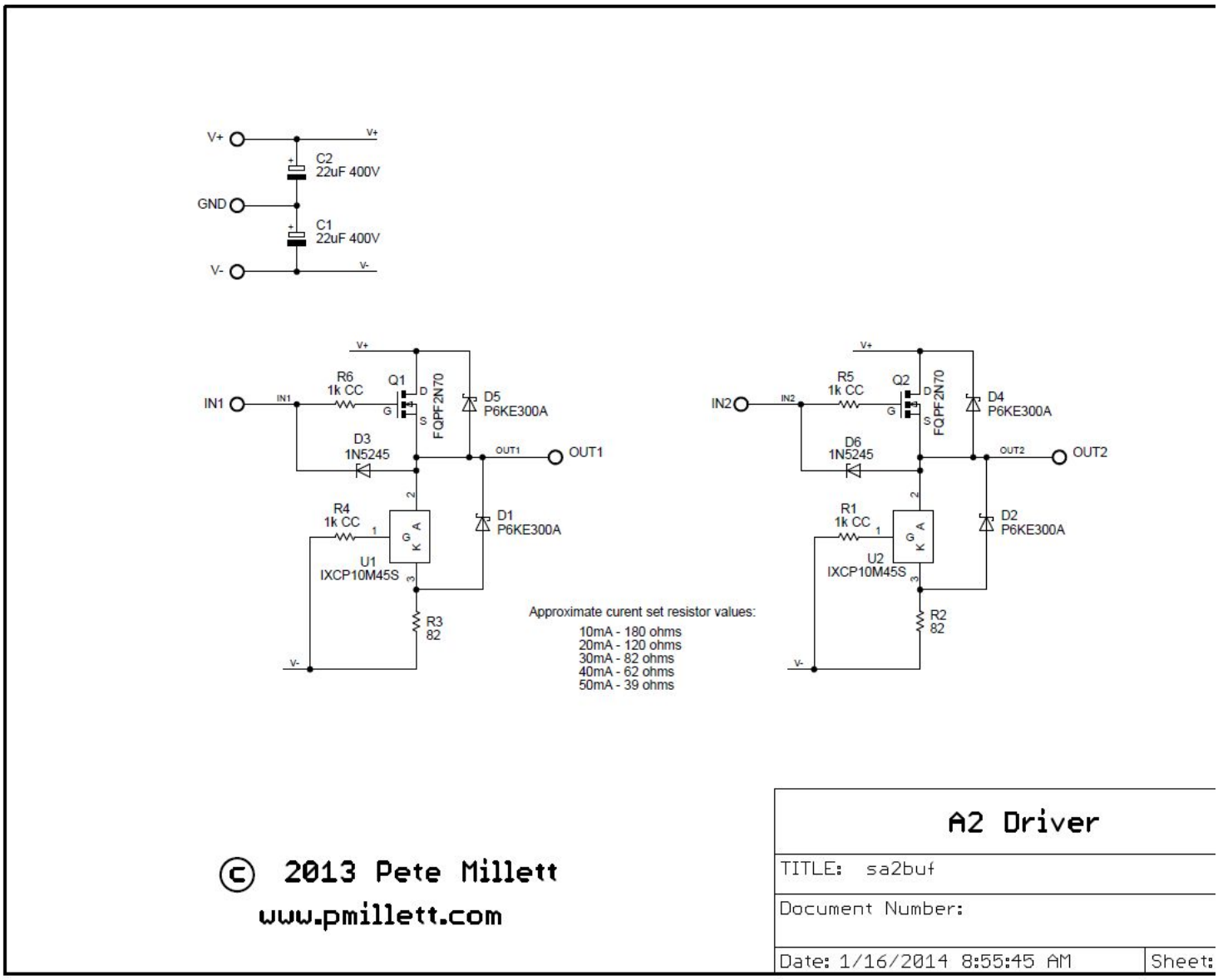
You can download a zip file with my FPE front and rear files here.

I'm waiting to get the front and rear panels back from being laser-engraved. When I get them back I'll post photos of the whole thing put together. But really the guts are more interesting anyway :)

DIY Audio Home

MOSFET A2 buffer

Here's a circuit that can be used to provide current drive to the grid of a power tube to operate in class-A2 operation (or download it as a PDF file):



This is a simple N-channel MOSFET source follower, with a CCS load using an Ixys IXCP10M45S part.

The bias (standing) current through the buffer is set by R2/R3 above. It seems to be not too critical... I wound up using 100 ohms, which gives around 25mA through each of the circuits.

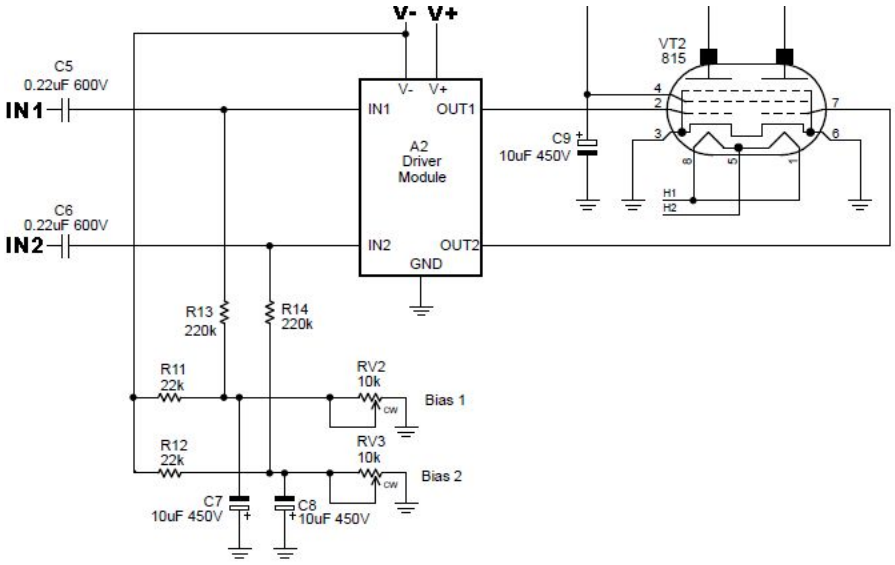
Zener diodes D3 and D6 protect the gates of the MOSFETs from transients that could pop the gate oxide of the FETs. The TVS devices D1/D2/D4/D5 provide protection for the FET and CCS part during transients, shorts, and power-up/power-down conditions. They technically are optional, but I would recommend they be used.

This circuit floats between a positive (V+) and negative (V-) supply. Technically, it has no ground connection (like an opamp). I did provide spots for filter caps on V+ and V-, so there is a GND pad on the board, but it only connects to the caps.

Power supply rails need to be somewhere beyond the maximum positive and negative swings you need on the output. They can be considerably higher if you want, limited by the FET and IXCP10M45 breakdown voltages. I use +250V and -100V for the 815 amplifier. Do keep in mind that the power dissipation goes up with the voltage, since this is a constant-current buffer. Also, dissipation will go up when delivering large currents to the output.

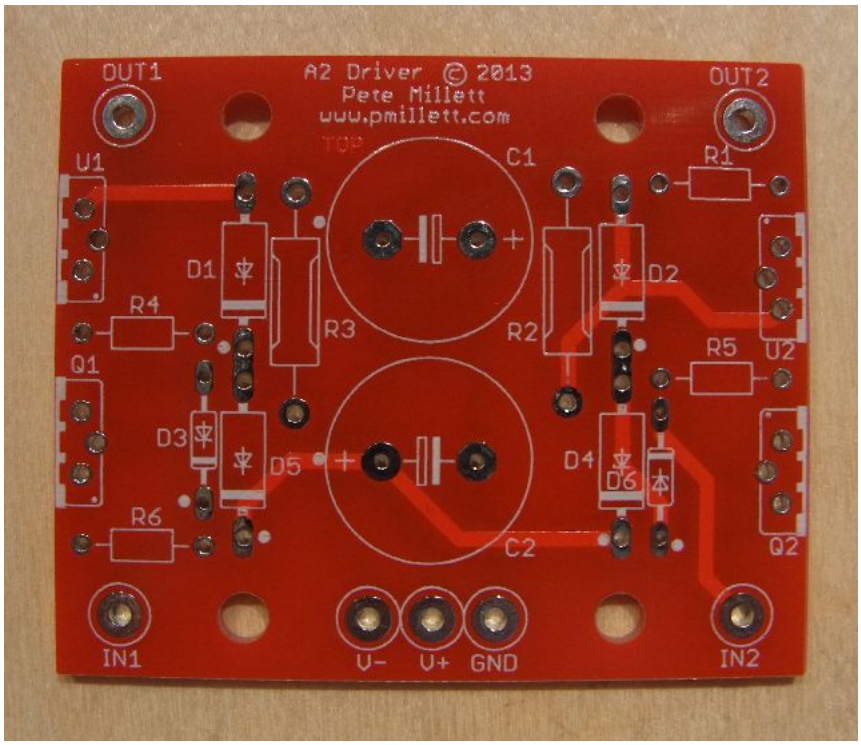
Note that there is no bias network on the input to the buffer. You need to provide some DC bias, just like you would to the grid of a tube, and AC-couple the signal into the input with a coupling cap. The output will track ~4V lower than the input. A simple resistor to ground will give you about -4V on the output, which works well for quite a few "zero bias" transmitting tubes.

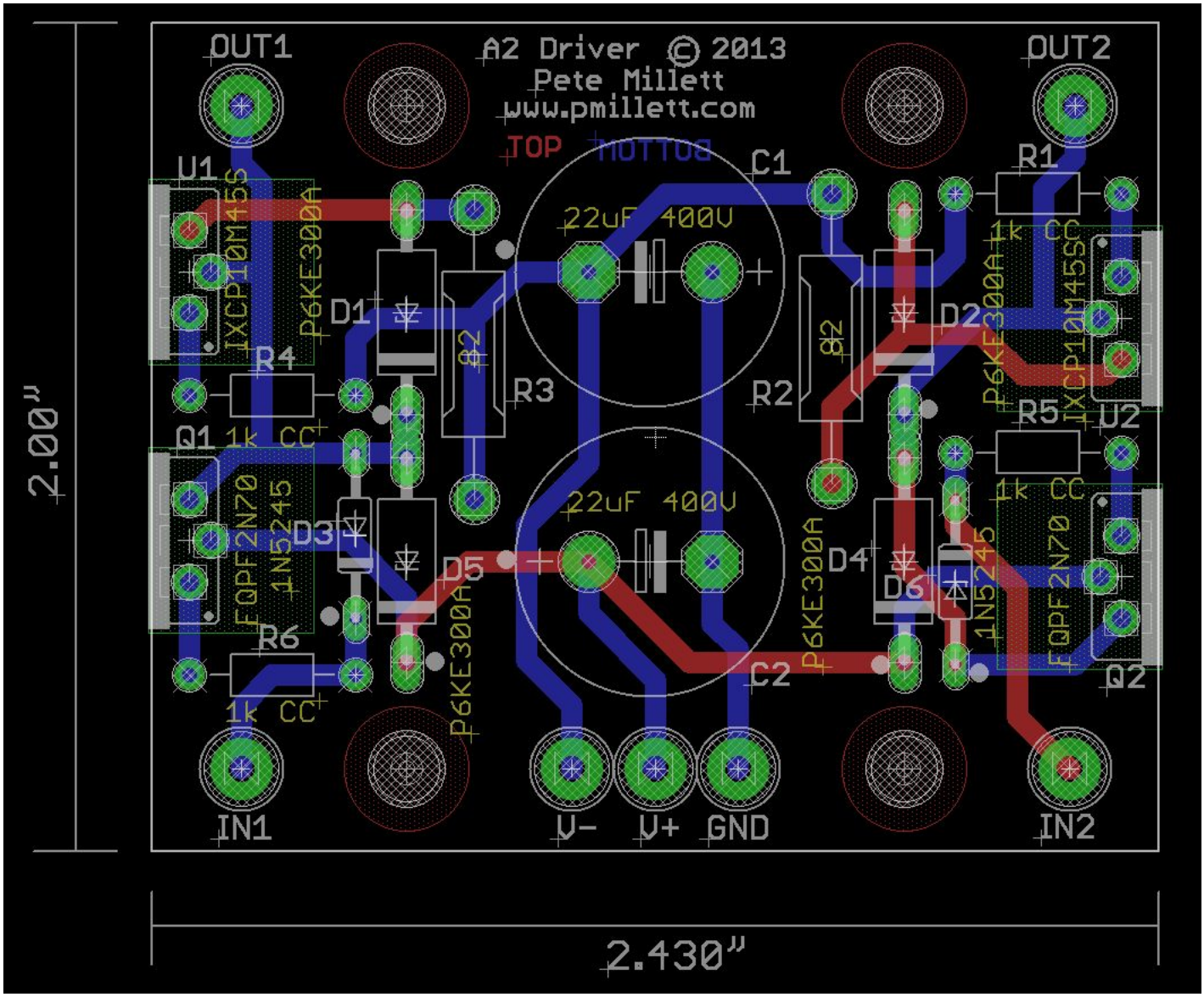
Here is an example of how it's hooked up (showing driving the grids of an 815):



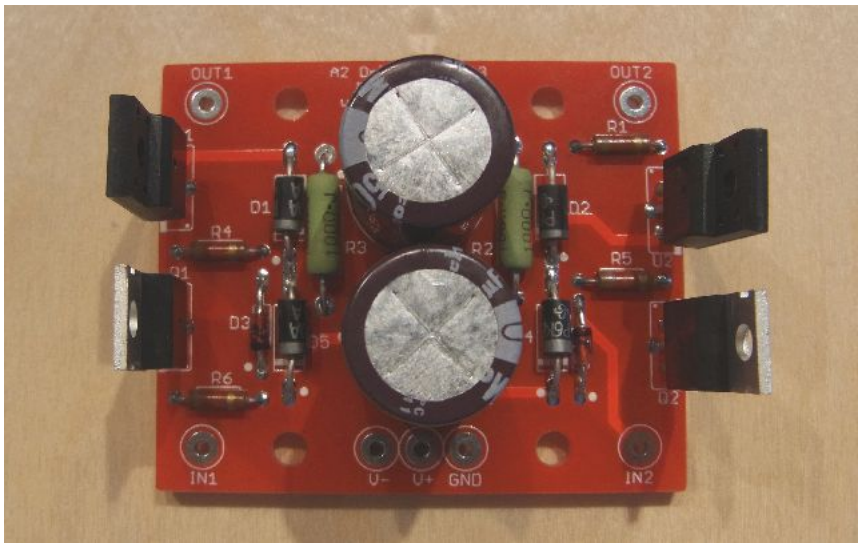
Another application for this would be to drive the screen grid of a power pentode (or beam tube). In this case you could DC-couple the input to the plate of a driver tube. The output will sit just below the voltage on the plate of the driver, which is just right for screen drive.

Here is the PCB, available on eBay:



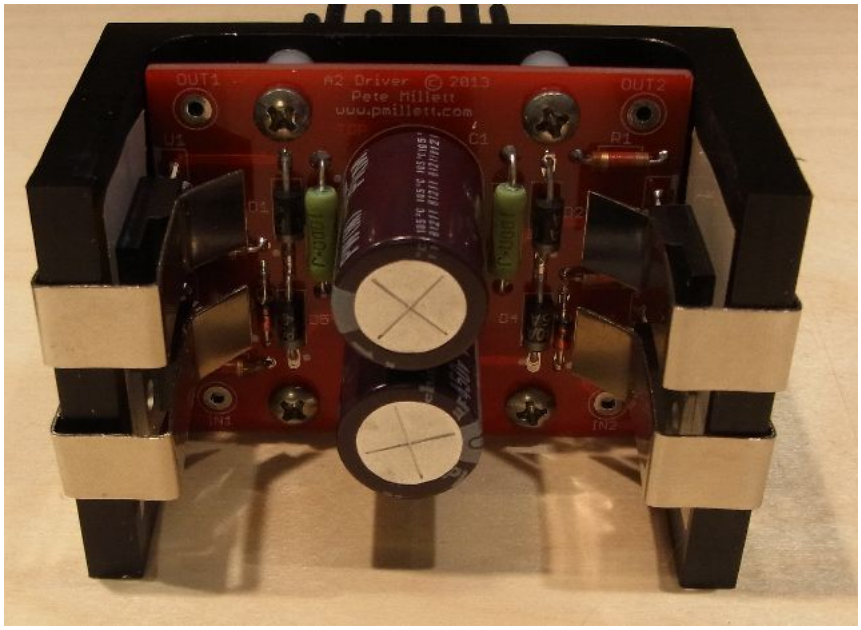


The assembled PCB:



One little note - on Zener diode D6, the silkscreen label isn't visible because it's underneath D4. Also, the cathode dot on the silkscreen is at the wrong end - follow the component outline to locate the cathode end).

...and the PCB assembled onto the heatsink:





The heatsink is a very cool device (literally?) that I developed along with Landfall Systems. It allows you to get the heat generated up and out of the chassis. You just have to drill or punch one big round hole for the heatsink pegs to stick out of the chassis, and two small holes to mount it using screws.

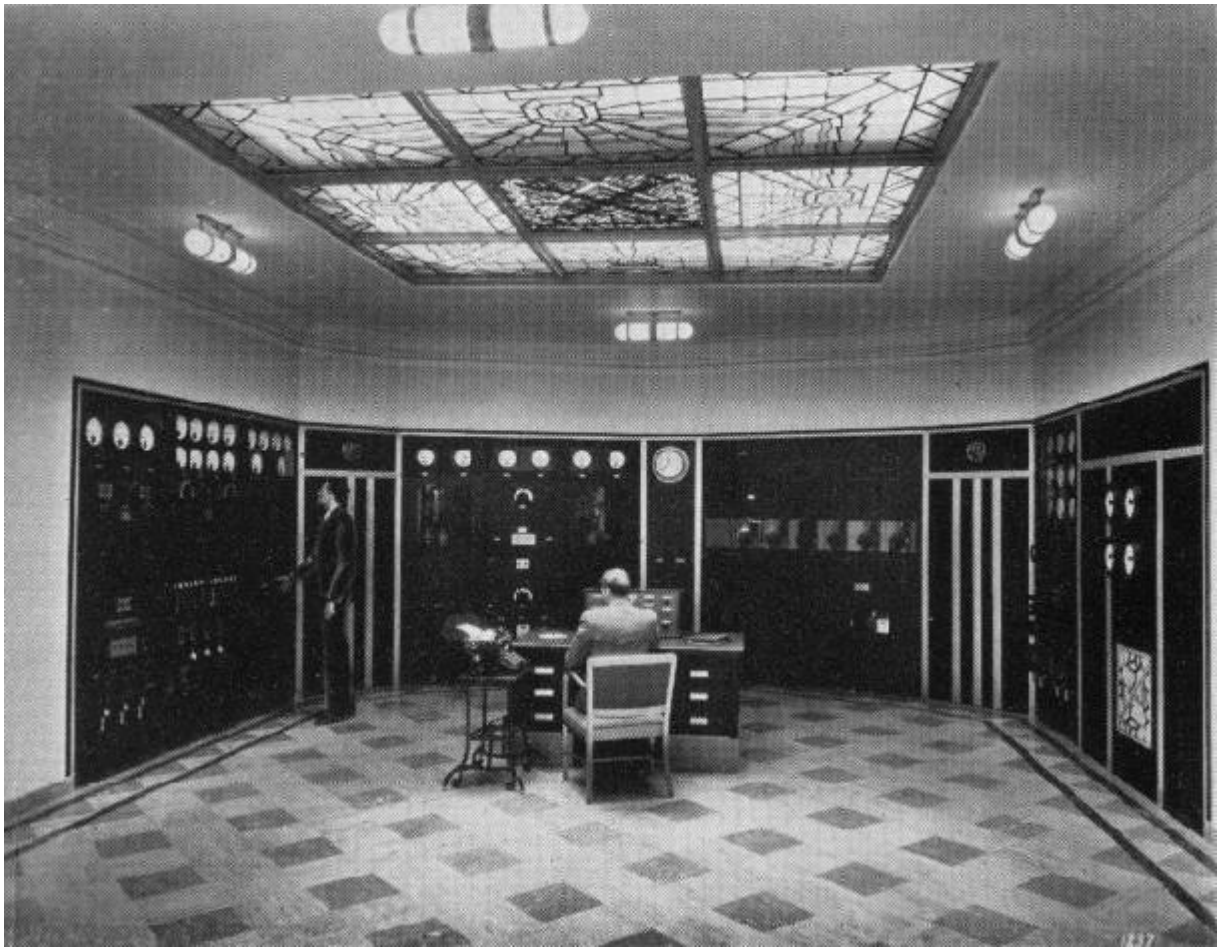
Contact Landfall about the heatsink. You can also get a prototype bard from them that lets you build your own circuit using this heatsink.

Note that you need to space the power devices such that the bottom of the plastic body is about 1/4' above the PCB, so that the heatsink and clips correctly mate with the heatsink.

You can of course use some other heatsink method if you prefer.

You can download the BOM in PDF or XLS format. All the parts can be gotten from Mouser.

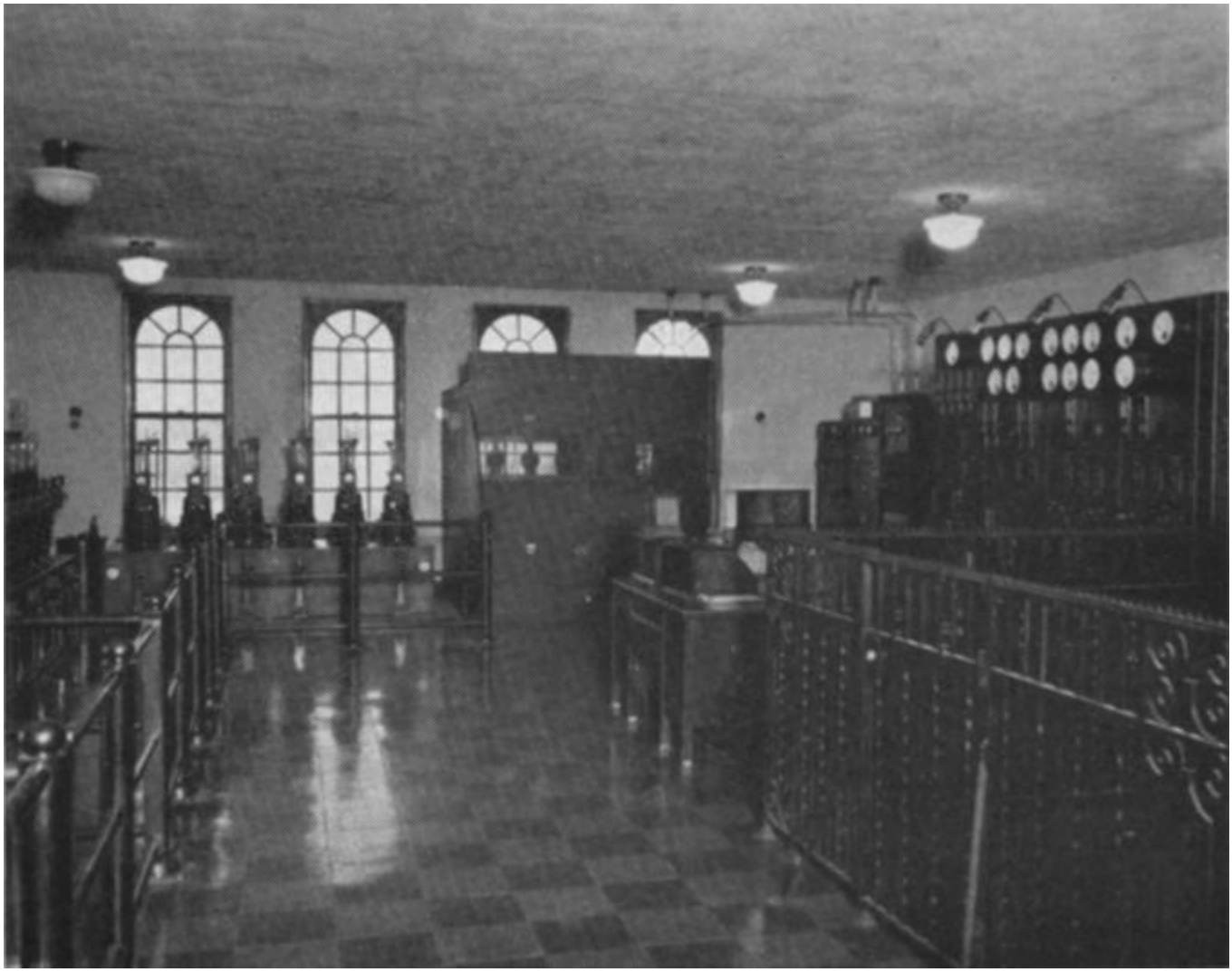
RCA-50B 50kW Broadcast Transmitter
Power For Radios Golden Age



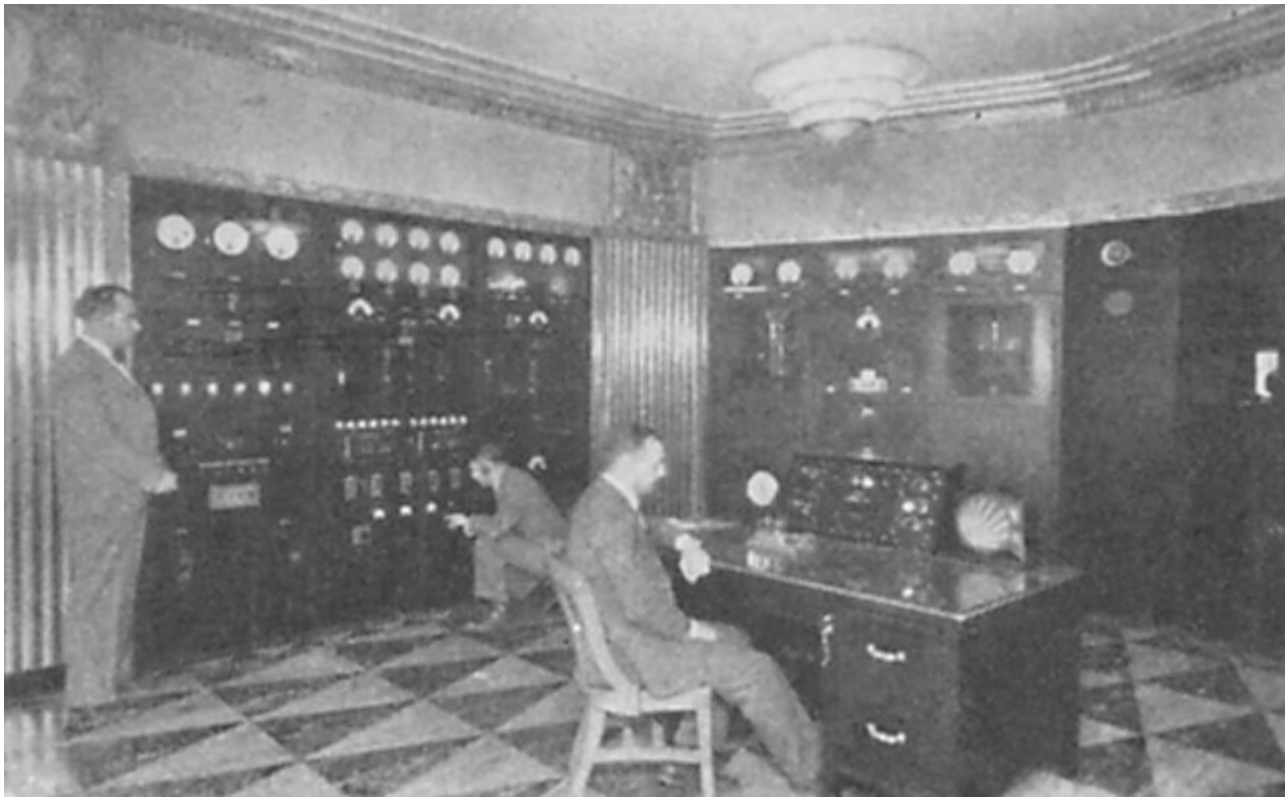
This is a photo, from about 1935, of the RCA-50B 50 kW AM Broadcast Transmitter installed at station KOA in Denver. The RCA-50B Transmitter was installed by many Class 1A 50 kW clear channel stations during radios golden age in the 1930's. NBC's owned and operated stations in Chicago, Denver, New York, and San Francisco, all used the RCA-50B transmitter. NBC's RCA-50B transmitters, installed in the 1930's, remained in service until they were replaced in the early 1960's. The 50B transmitters were manufactured for RCA by the General Electric Company, and the Westinghouse Electric and Manufacturing Company. An article describing the RCA-50B Transmitter can be found in the October 1930 issue of the Proceedings of the Institute of Radio Engineers titled, "Some Developments In Broadcast Transmitters". The 50B transmitter consisted of a 50 kW linear amplifier using two water cooled UV-862 tubes in a push pull circuit, which was driven by an RCA-5B 5 kW transmitter. As can be seen in the photo of the 50B installed at KOA, the 50B consisted of 4 main units. The panels in the left side wall are the 5 kW driver transmitter. The panel on the left side of the rear wall is the 50 kW linear amplifier, while the panel on the right side of the rear wall is the main rectifier. The control panel is on the right side wall.



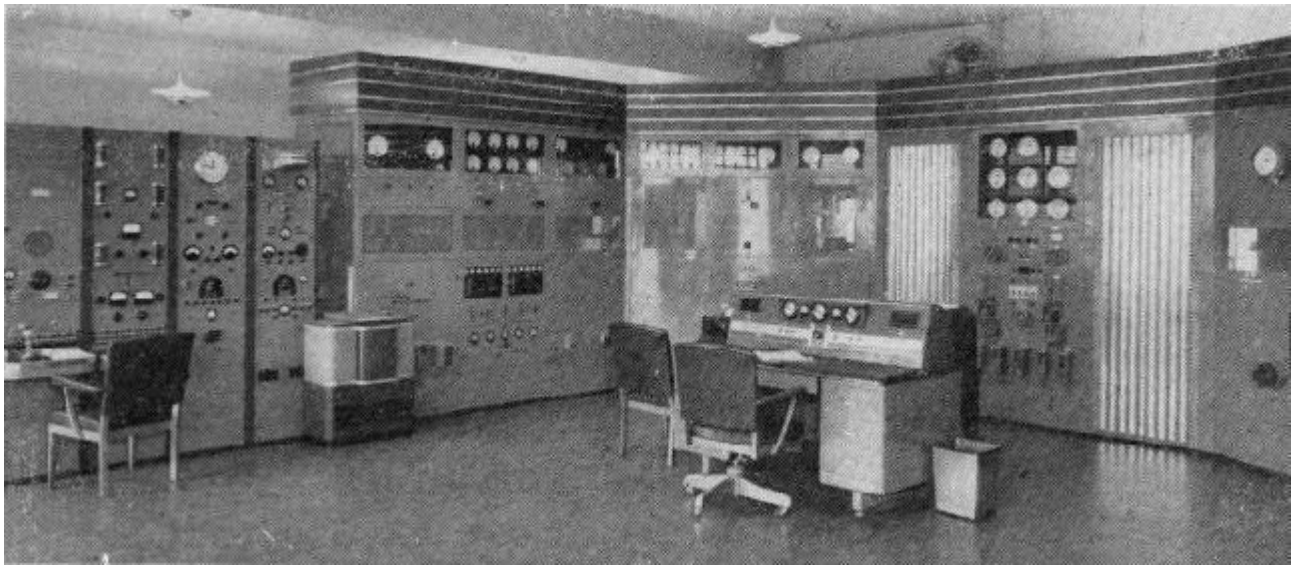
This is the RCA-50B transmitter at WENR in Chicago as it appeared in a 1932 photo. The 50 kW linear amplifier of the 50B appears at the right rear, while the control equipment for the transmitters appears to the left in the photo. WENR's RCA-50B was later replaced by a new RCA-50D, and WENR's old 50B was moved to WEAF's new Port Washington site in 1940.



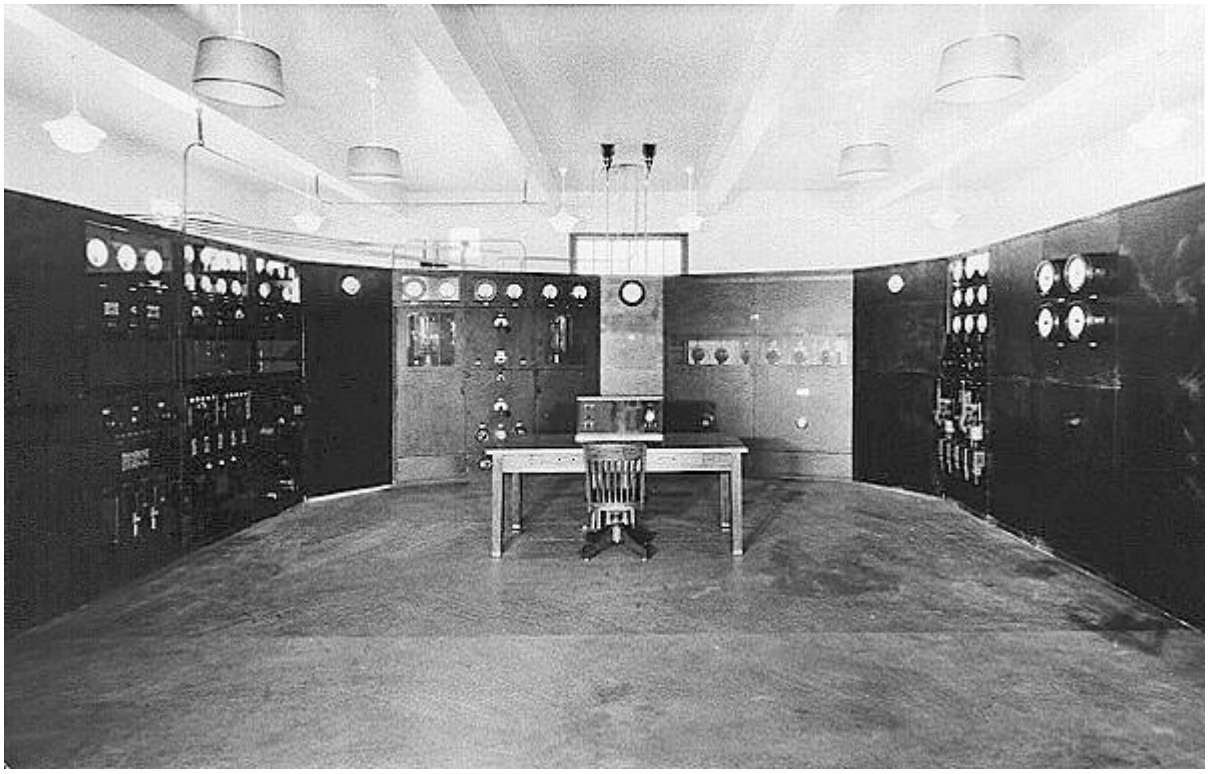
The Rectifier for the WENR 50B is at the center rear in this 1932 photo. An older transmitter of open construction appears behind the railing on the left, and in the rear of the photo adjacent to the rectifier for the 50B.



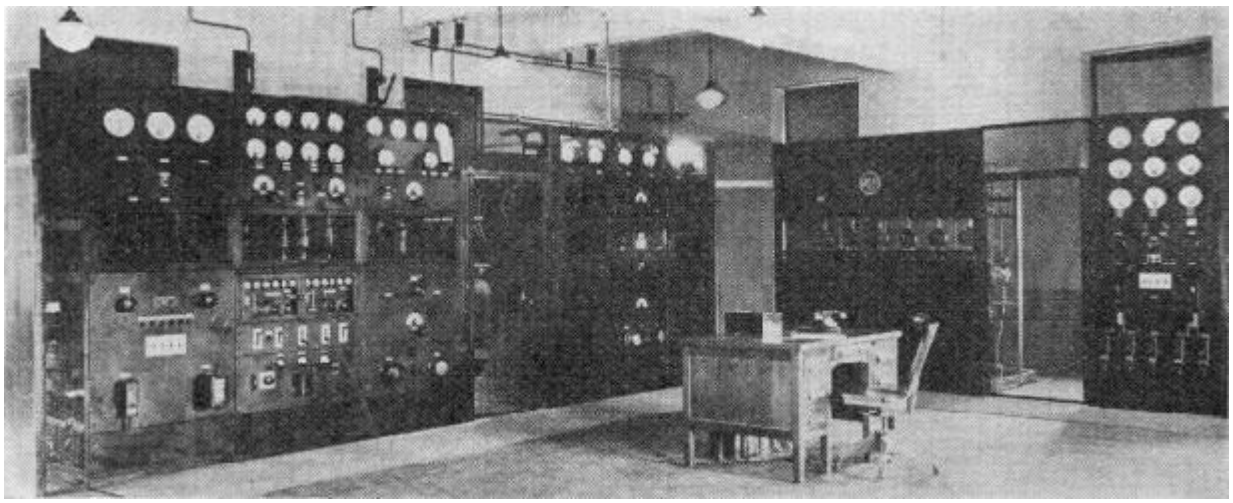
This 1932 photo shows WEAF's first RCA-50B transmitter which was installed at Bellmore Long Island. This transmitter remained behind at Bellmore to maintain continuity of service while WEAF moved to their new Port Washington Long Island site in 1940.



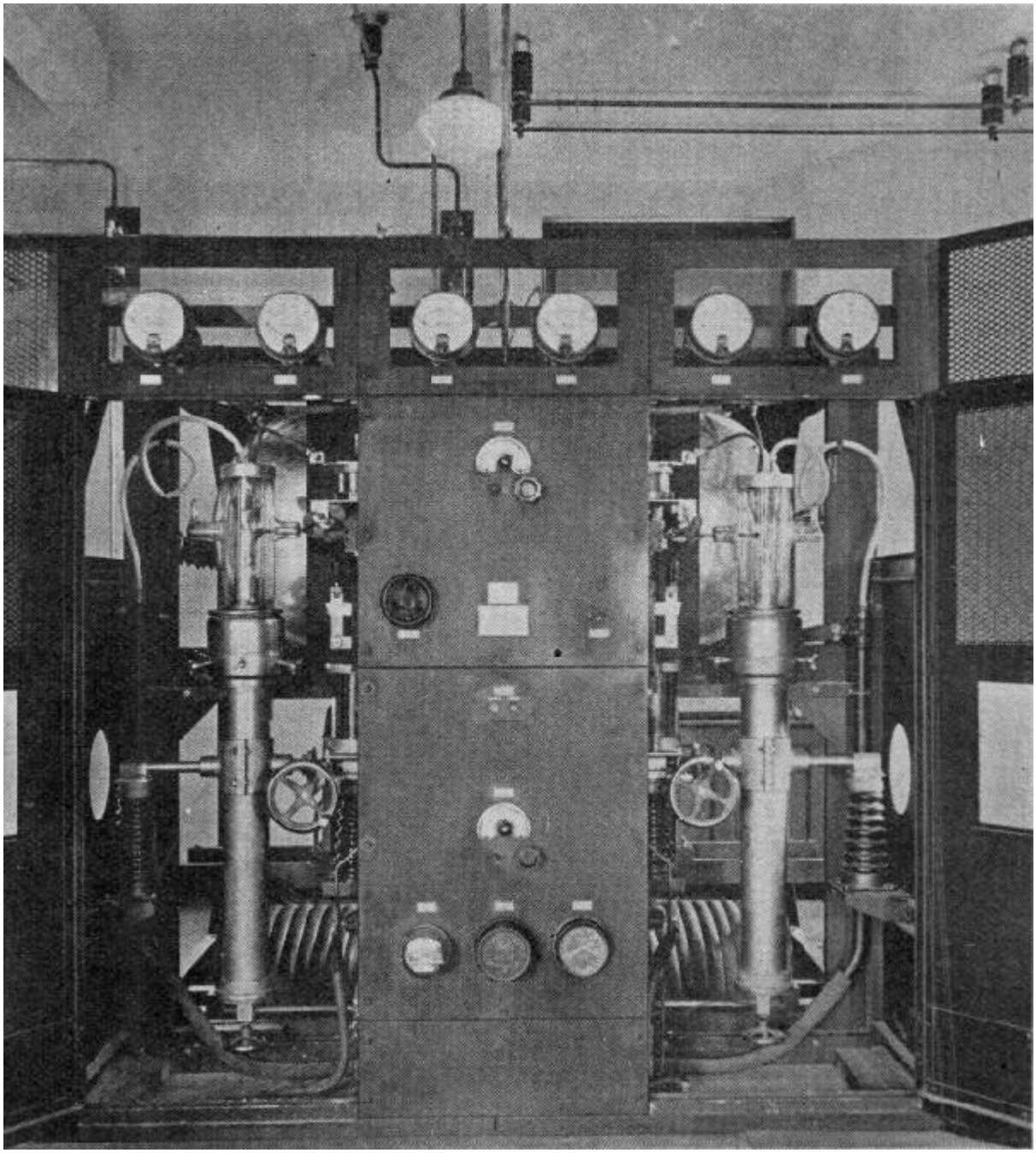
This 1940 photo shows the old WENR RCA-50B 50 kW AM Broadcast Transmitter as it looked after it was installed at WEAF's new Port Washington site in 1940. It can be seen that WEAF's "new" RCA-50B has been dressed up with stylish modern trim. Only the 50 kW linear amplifier and rectifier were moved from Chicago to New York. WEAF used an existing spare 5 kW transmitter, with extensive modifications, to drive the 50 kW amplifier. Over the years most 50B transmitters underwent similar modifications to upgrade their performance. The control panel was installed between the 50 kW linear amplifier and the main rectifier, rather than the typical location to the right of the main rectifier. NBC eventually changed the call letters of station WEAF to WNBC. To see how RCA and NBC converted WNBC's RCA-50B transmitter for AM Stereo operation in 1959, Click Here



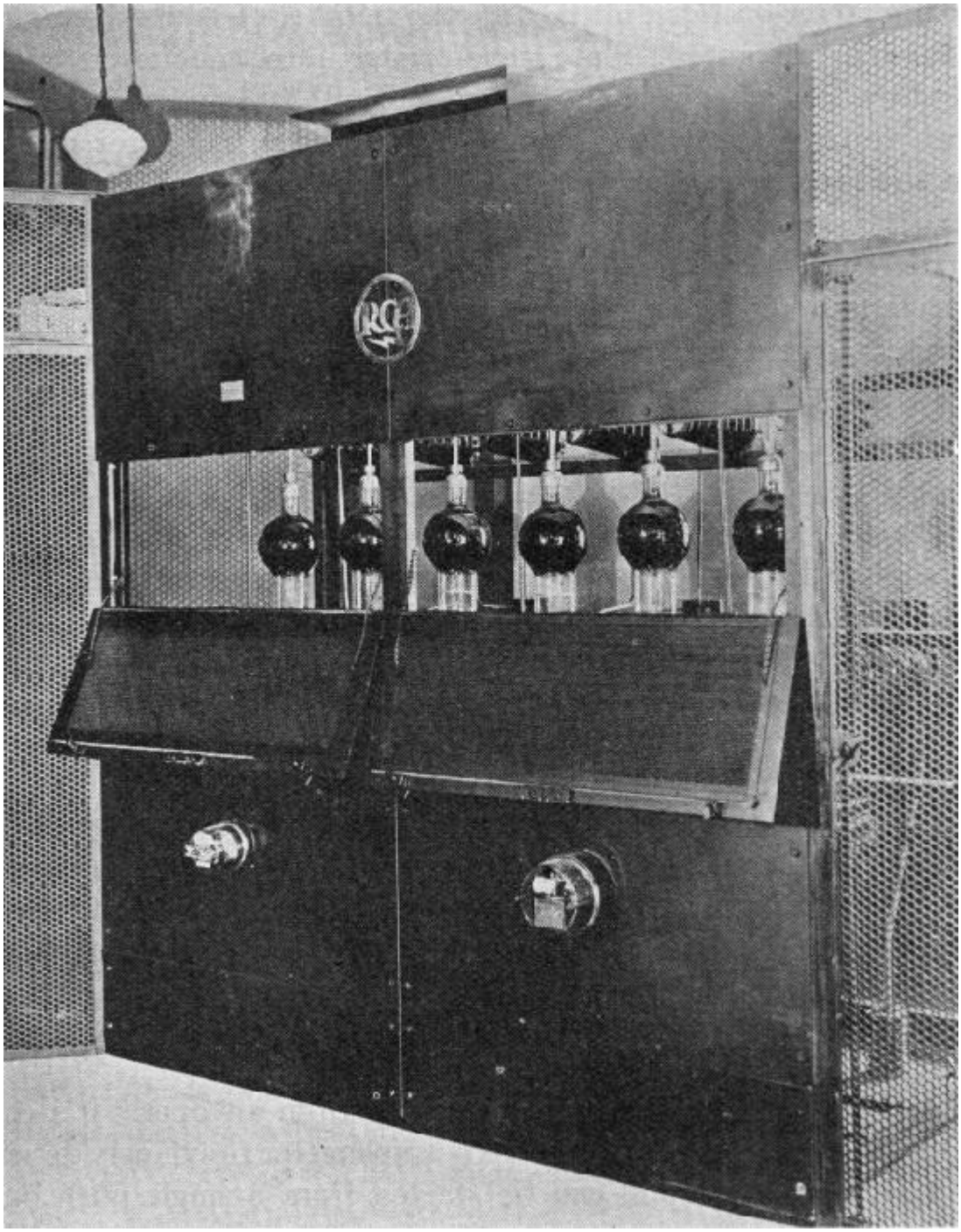
This is the RCA-50B 50 kW AM Broadcast Transmitter installed at station KPO in San Francisco. As can be seen, KPO's installation of the 50B is very similar to that at KOA.



This is the first RCA 50B which was installed in 1929 at WTIC of Hartford. It was known by RCA engineers as "Number One" of its type, and was the first high power commercial transmitter to use 100-kilowatt tubes, the first to use mercury-vapor type rectifiers throughout, and the first capable of 100 percent modulation of its full rated 50-kilowatt carrier output. Notice the RCA logo on the main rectifier cabinet in this 1930 photo.



This is a view of the 50 kW linear amplifier cabinet for WTIC's "Number One", with the doors open to show the two water cooled UV-862 tubes.



This is a close-up view of the Main Rectifier cabinet for WTIC's "Number One" 50B Transmitter, showing the RCA logo.

Thanks to John Schneider for the photo of KPO's RCA 50B Transmitter. You can learn more about the history of KPO on John's web page:
Belmont Visit.

Thanks to Jim Hawkins for the photo of WEAF's first RCA 50B Transmitter. You can learn more about WEAF's successor on Jim's web page:
WCBS/WFAN Transmitter Tour.

I would be interested in hearing from anyone that has any additional information on the RCA 50B Transmitter. I am especially interested in finding a photo of the RCA 50B transmitter installed at WMAQ in Chicago, and a copy of the Instruction and Operating Manual for the RCA 50B Broadcast Transmitter. I can be reached by email at byrnsj@sbcglobal.net.

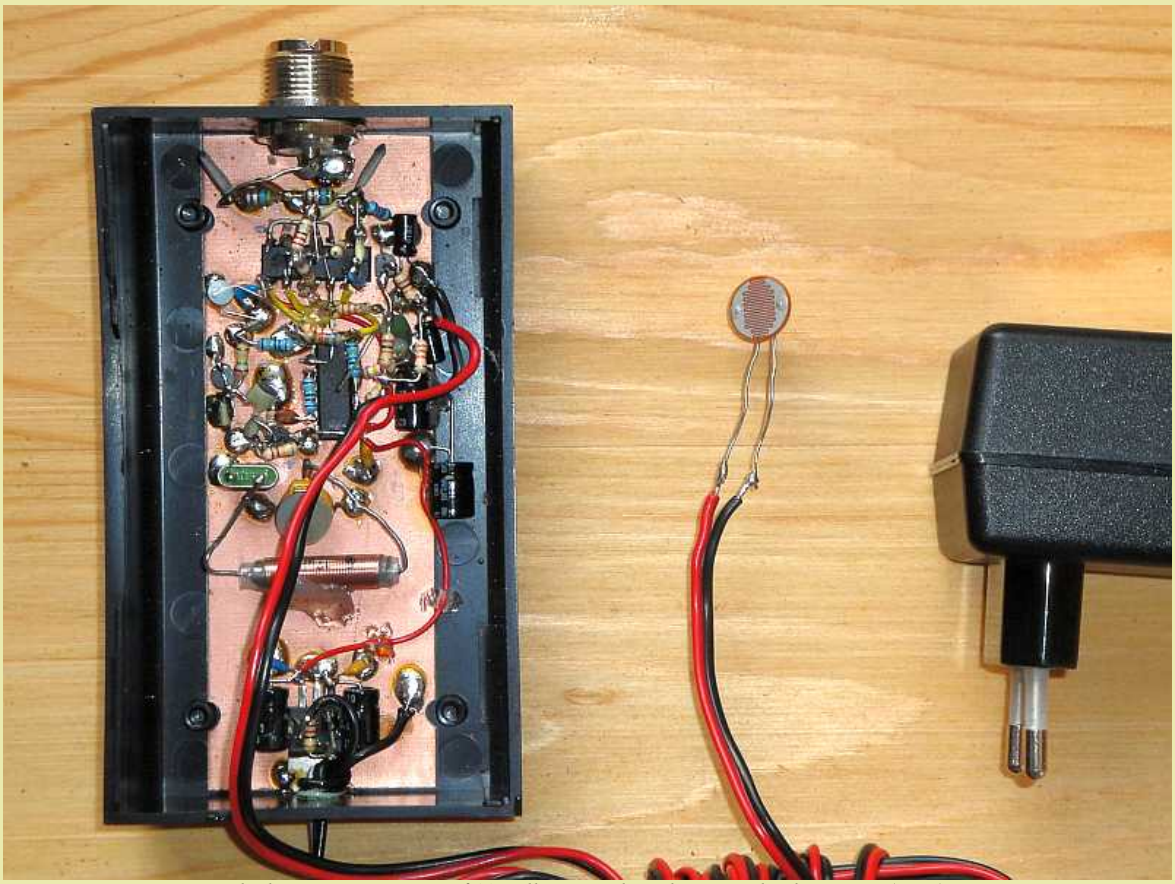
4/12/04

John's Home Page

10 MILLIWATT QRSS BEACON TRANSMITTER FOR 30 METER KEYED BY A WEBBROWSER

(2010)

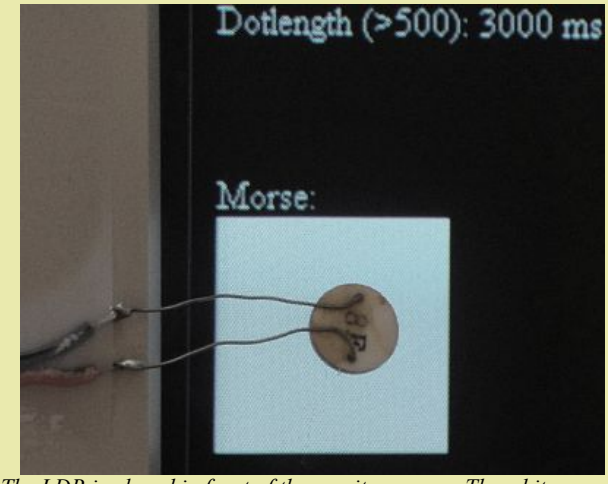
KLIK HIER VOOR DE NEDERLANDSE VERSIE



The beacon transmitter of 10 milliwatt with Light Dependend Resistor (LDR).
The beacon transmitter is keyed by the LDR.

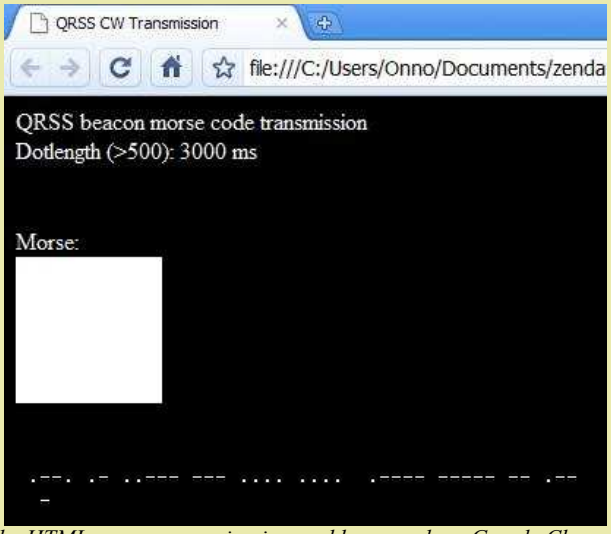
Experiments with very low power QRSS beacon transmitters

There is a group enthusiastic radio amateurs that is doing experiments with very low powers. That is possible by using a low CW speed (QRSS speed). Most of the activities can be found in a band of only 100 Hz, namely 10140.0 to 10140.1 kHz in the 30 meters amateur band. Signals are decoded with a special software program. My beacon transmitter could only be frequency modulated with a square wave with a frequency shift of 4 to 5 Hz. But for the serious work, in morsecode the call, QTH locator or transmit power had to be transmitted. But how can that keying with morsecode be realized?



The LDR is placed in front of the monitor screen. The white square on the screen blinks on/off in the rhythm of the morsecode.
This is done by a HTML program running in a webbrowser.

Keying with a webbrowser
It was not easy to find a simple solution for keying the beacon transmitter with morsecode. Mostly, a micro controller circuit is used. But how can you key the transmitter with a PC? A printerport and RS232 port are history. It can be done with a special interface for the USB port. But which software do you have to use for that? And that works of course only with Windows-XP, but not with Vista...
Then I had the idea to use software that you can find on every PC, namely a webbrowser! We make a simple HTML program that does blink a square on the monitor screen white/black in the rhythm of the morsecode. In front of that square, we place a light dependent resistor that keys the beacon transmitter. That works for all operating systems, Windows 95 to Windows 7 and newer, Linux, MAC-OS, the webbrowser controls everything! And we do not have to buy or hack and install software. And everyone can modify the program with a simple ASCII text editor (Notepad) to his own demands. It does not have to be a fast program and the timing is not critical. A dot lasts 3 second and a dash 9 seconds. Is that dot or dash a little longer or shorter, nobody will notice that.



The HTML program running in a webbrowser, here Google Chrome.
The white square blinks on/off in the rhythm of the morsecode.

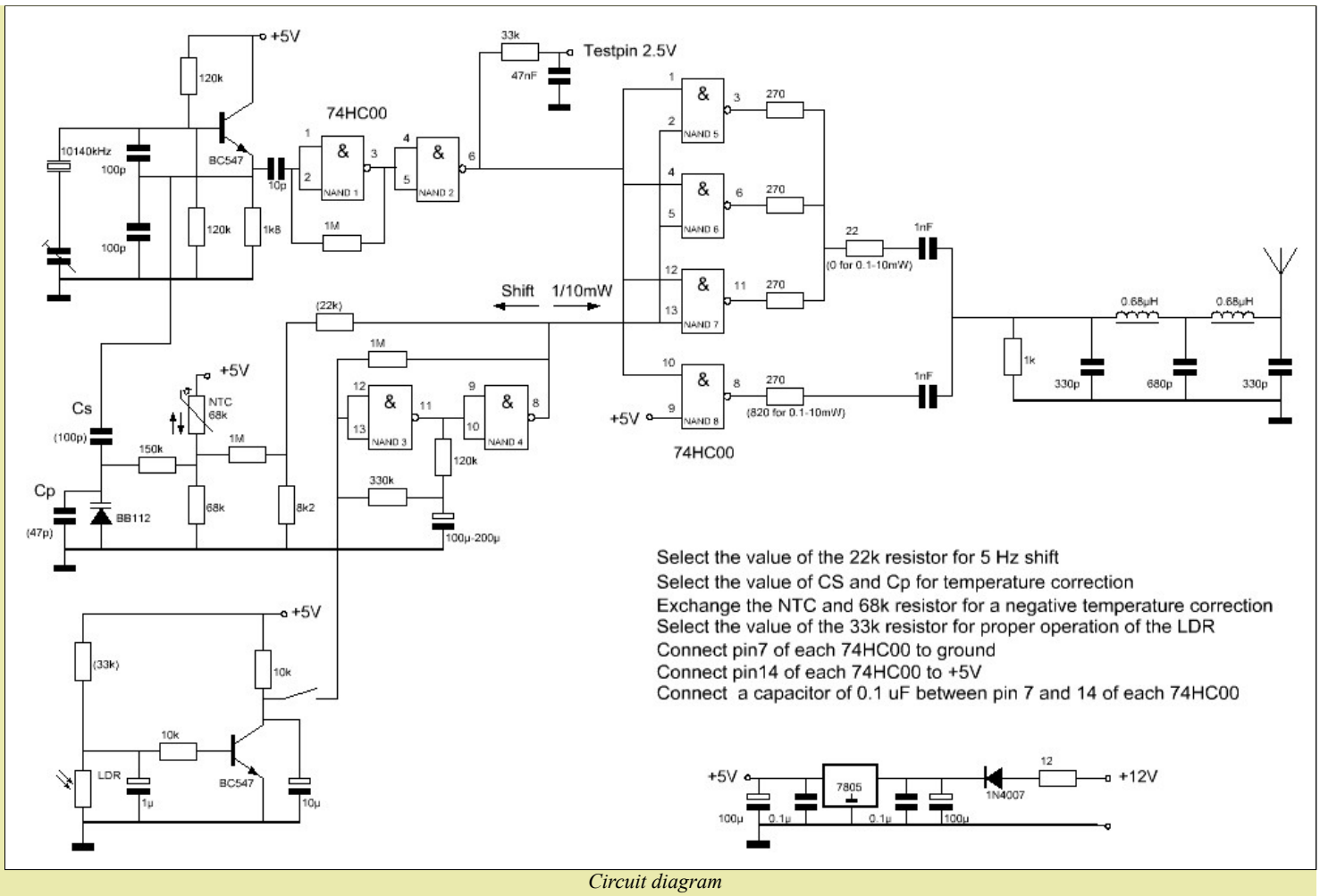
The program
The program is using Javascript, that has to be enabled in the webbrowser. But normally that is already the case, most HTML applications on internet do use Javascript.

Click here to see the HTML program running, that will make clear to you how it works.

Click here to download the zipped version of the HTML program.

Click here to download a zipped version that transmits in time synchronized 10 minute intervals.

You can modify the program by means of an ASCII text editor like Notepad. In one of the first lines after "Data", you have to fill in the desired morsecode. And after dottime the keying speed in milliseconds (normally 3000 ms for a dot). By means of style sheets, two squares are defined, a white square and a black square. And by means of a timer interrupt routine named "function NewTime()" and the function "innerHTML" for modification of a part of the screen, everything is controlled. After that the morsecode is transmitted, the HTML program is loaded again and run by the webbrowser. During a transmission, it is possible to modify the HTML program. I can do that from any location, as together with the webbrowser, a FTP program is also running on the PC. But there are other possibilities for that. And on the PC, also the program ARGO with simple receiver is running, so that I can see from a remote location if everything is going well.

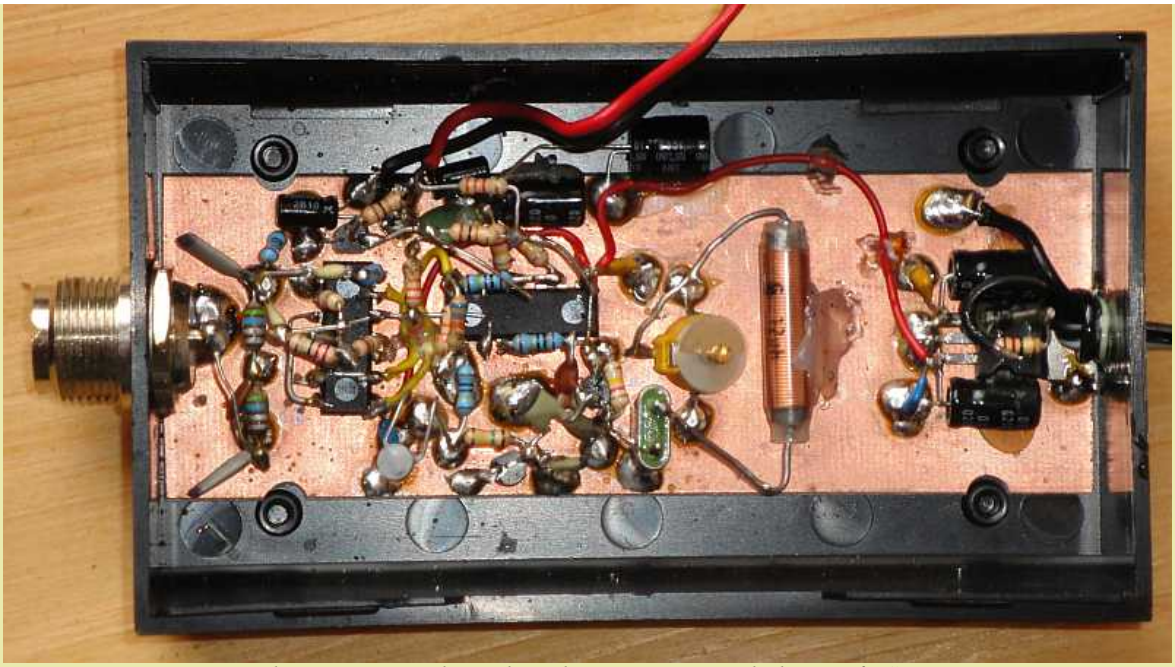


Circuit diagram
big diagram

Description of the circuit diagram of the transmitter
A crystal oscillator with a BC547 transistor is buffered by NAND1 and NAND2 and amplified by NAND5 to 8. The circuit with NAND3 and NAND4 is a square wave oscillator. When the switch is opened, the transmitter is frequency modulated by this square wave. But also in amplitude. During the positive half of the square wave, NAND5 to 8 are all switched on and the transmit power is 10 mW. During the negative half of the square wave, only NAND8 is active and the transmit power is only 1 mW (or 0.1 mW, depending on the used resistor values). When the switch is closed the transmitter is keyed by the LDR. The capacitors of 1 uF and 10 uF do suppress the flickering of the screen and other interferences.
During the transmission of a dot or dash, the transmit power is 10 milliwatt. During spaces, the transmit power is 1 milliwatt (or 0.1 mW, depending on the used resistor values) and the transmit frequency is lowered with 4 to 5 Hz.

Temperature stabilization
The frequency has to be very stable. It is quite difficult to adjust the beacon transmitter on a frequency of 10140.0 tot 10140.1 kHz and to avoid drift due to temperature changes. A temperature correction circuit was made with a NTC resistor and a varicap. The drift could be reduced considerably. For a positive frequency drift correction, you have to connect the NTC in accordance with the diagram. For a negative correction, the NTC resistor and 68k resistor have to be exchanged. Of course you can also take a NTC resistor with a different value. Exchange the 68k resistor then for one with the same value as the NTC. Increasing of Cs and reducing Cp increases the correction, reduction of Cs and and increasing of Cp does reduce the correction. Finding the correct value is done by of trying out various values of Cs and Cp while cooling down and warming up the transmitter.

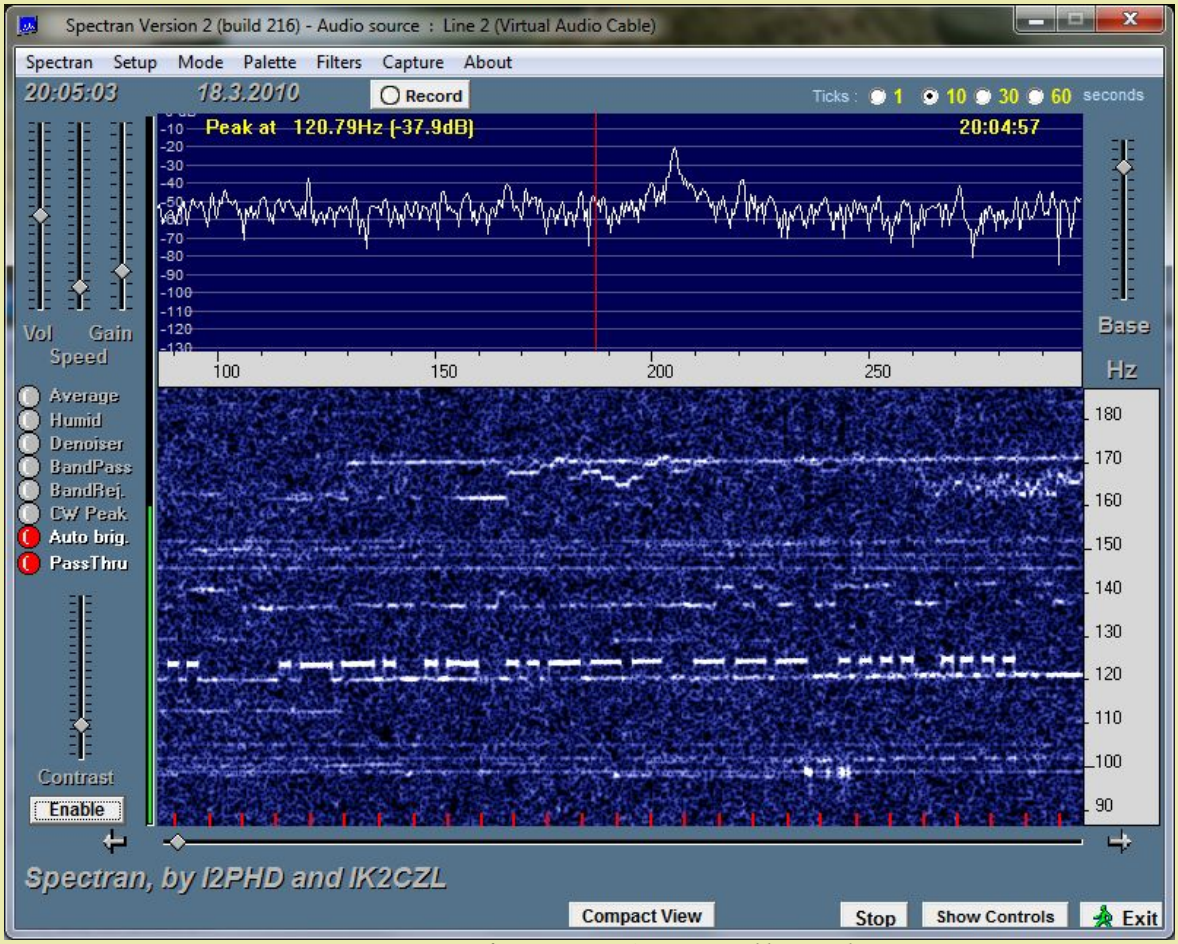
The Light Dependent Resistor (LDR)
It is important to keep a distance of at least 0.5 cm between the screen and the LDR. Otherwise, the high voltage of the screen can disturb the LDR. The flickering of the screen has also to be filtered out. And you have to avoid interference from daylight by screening the LDR and screen with a piece of cardboard or so. By using a LDR we have a full galvanic isolation between the PC and the 10 milliwatt beacon transmitter! Of course you can modify the program so that you have a second square with second LDR to switch other things like power or switching between transmission and reception.



The circuit mounted in a plastic housing on an unetched piece of PCB.
An extra coil in series with the crystal was necessary to tune to the correct frequency.

Construction
The circuit is mounted in a plastic housing on an unetched piece of PCB. That is simple, quick and it is easy to change the circuit. That last advantage is very important, the final design was modified considerably. The transmitter is supplied by an AC/DC adapter.

Results
It is a strange experiment. The 10 milliwatt transmitter is switched on and... The needle of the power meter does not move! And it is even a QRP power meter! But how do you get reception reports? Quite soon I received an e-mail with screenshot from Dusan, YT1DL. Dusan many thanks, with this report the experiment was already 100% successfull! Not only the high shift with dots and dashes with 10 milliwatt was visible, also the lower shift with pauses between the dots and dashes of 1 milliwatt was visible! Dusan does not use the program ARGO but Spectran.



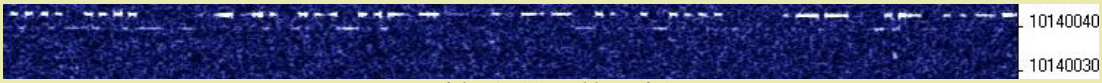
Reception report from Dusan YT1DL, received by e-mail.

Not only the 10 mW, but also the 1 mW shift (pauses, 4-5 Hz lower) is visible.

But there are other possibilities to collect reception reports. There are amateurs who have their receivers coupled to internet. The reception results are continuously refreshed. You can see these results on internet (Search via Google for "QRSS grabbers"). The results here below are obtained via these QRSS grabbers. Totally, the beacon transmitter has transmitted during 3 days.

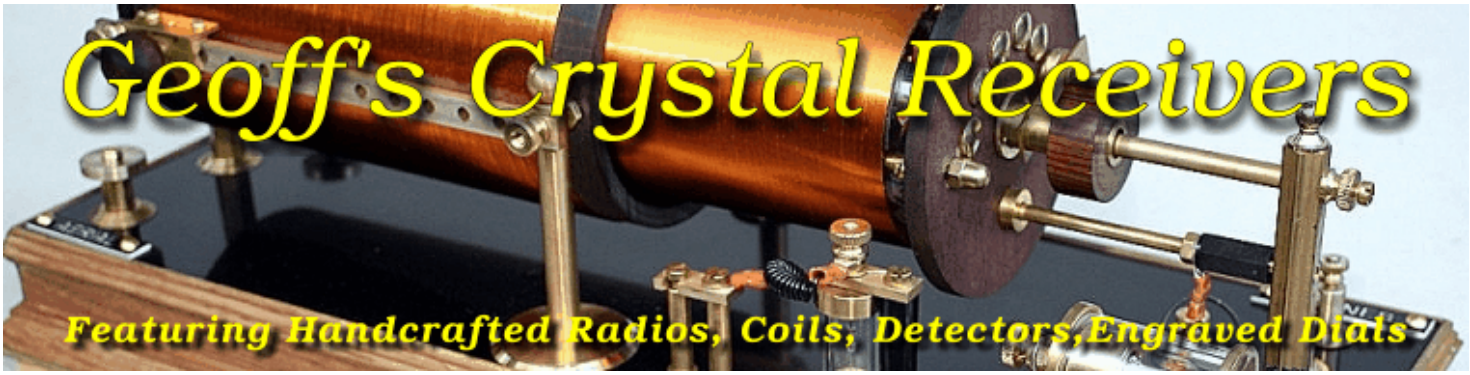


Reception report of the QRSS grabber of G4CWX in Bristol.
Also here the 1 mW shift (pauses, 4-5 Hz lower) is visible.



Reception report of the QRSS grabber of I2NDT in Bergamo.
Also here the 1 mW shift (pauses, 4-5 Hz lower) is visible.

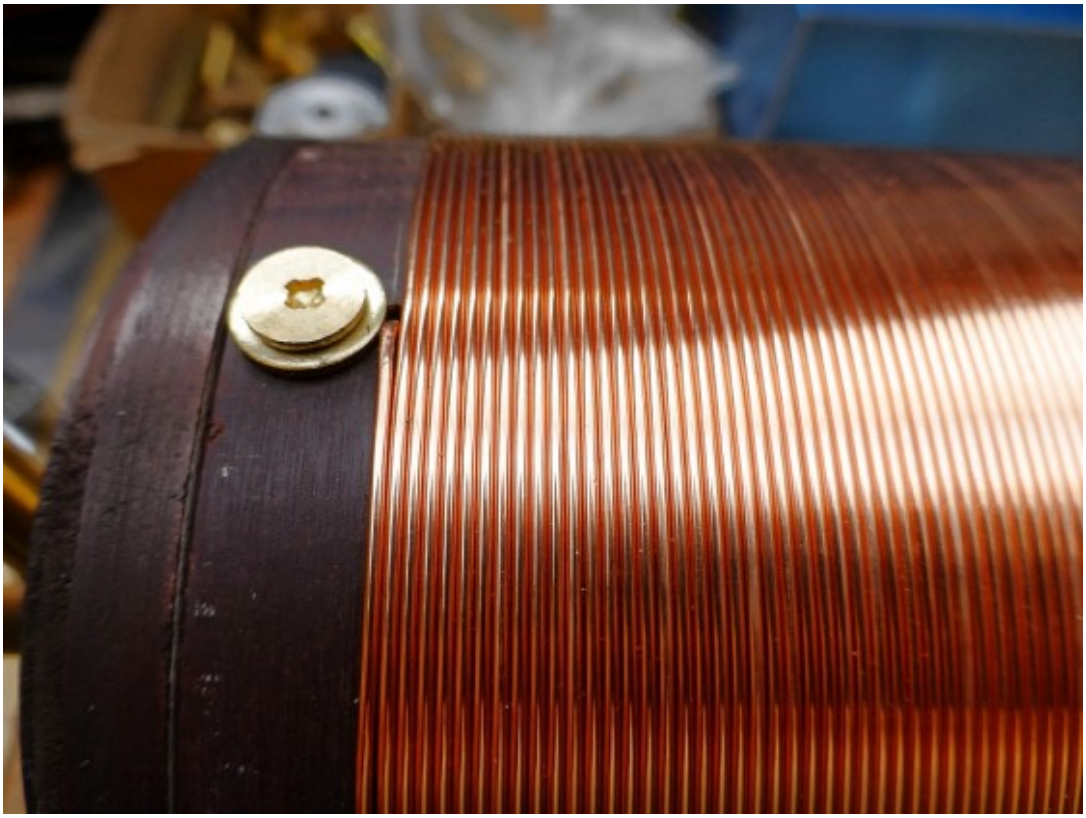
BACK TO INDEX PA2OHH



Inside Geoff's Workshop

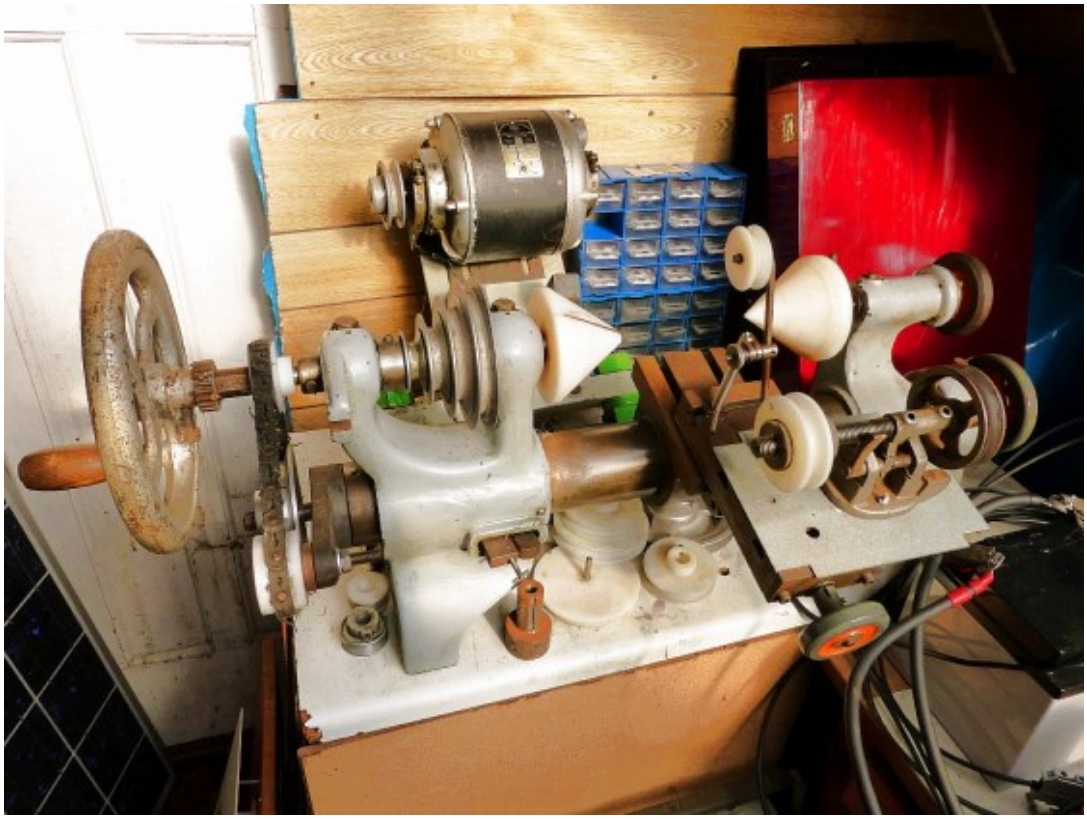
By Geoff Roberts, G8DHI

Winding A Radio Coil



The coil was wound on a 4 inch Diameter Paxolin former/tube. Paxolin is a material no longer manufactured. It was used extensively in the Radio industry in the early years from 1920's up to the late sixties. Paxolin is dry to RF and does not have a dampening effect on the inductance like some modern plastics. I found this piece at a local ham radio rally a few years back and snapped it knowing its rareness.

I have standardised on copper wire sizes for my projects ie 0.25mm 0.5mm and 1.00 mm this simplifies winding and calculation of number of turns as each is a fraction of 1mm. This coil was made with 1mm wire which is firm enough and thick enough to withstand the slider running over many times without breaking the windings. It was also easy to work out by practical means the pulley ratios for my winding machine with the 1 mm diameter wire.



It is very hard to wind a coil by hand and the time factor if you do so is very slow and frustrating, so I set about designing a simple coil winder using an old Drummond Vintage round bed lathe. The lathe was never very accurate for brass turning in my workshop so I put it to better use as coil winder. The lathe has a lead screw and a traversing tool saddle which with the right combination of pulley wheels could wind accurately every time a very tight coil. It works a treat and I have made dozens of coils over the years.

The Coil former is supported between two nylon cones and can be tightened by moving the tail stock. The tube does not slip because I put a blade in the cone which just cuts into the former material to secure it on the cone. The wire is passed over the top nylon pulley and tensioned by the bottom pulley on the saddle traverse.



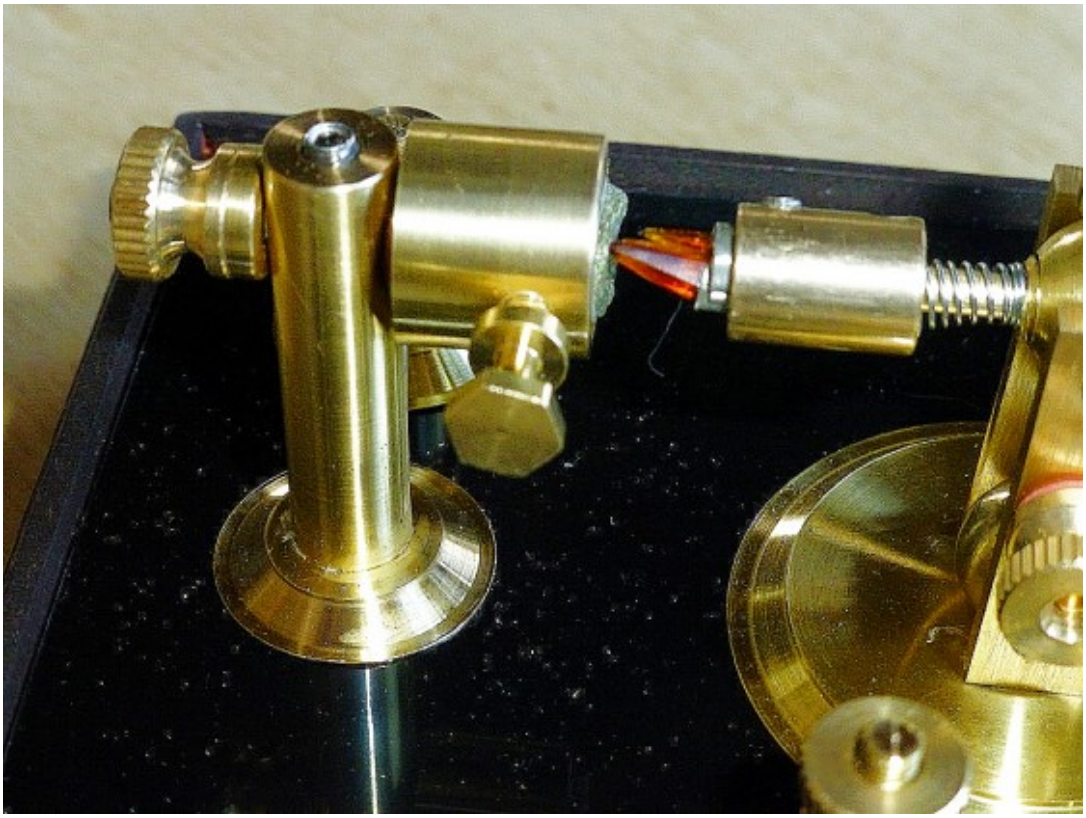
There are three pulleys on the back gear shaft which can be altered to give the lead screw the correct speed when hand turning the shaft. I had to make Nylon pulleys as there were no back gears available for this very old lathe when I bought it. With a little calculation of circumference it was easy to work out the ratios for my standard wire sizes. In bygon days simple machines like this were made by well know companies like AVO Douglas. It was a great project and works very well speeding up winding times and getting a very tight coil every time.

On a slider it is nessassary to secure the ends of the coil so that the winding does not spead apart with the friction of the slider. I did this by turning down a screw head for each end of the coil winding. See above photo. The winding length diameter and number of turns determines the inductance. I knew from previous loose coupler windings that I made that the coil would need to be 200mm to give me the 1000 µH for a Medium wave coil.

Here some of my handmade radio coils.

Bye for now Geoff.

Geoff's Perikon Detector



G W Pickard of the USA was a pioneer radio engineer in the early 1900's who invented the Perikon Detector and the Catwhisker Detector. For a detailed history of these please read the Wikipedia article.

I have made several of both of this type of devices but cannot praise more highly the virtues of the Perikon Detector compared to the more commonly known Catwhisker Detector(Galena and Gold wire) the Perikon Detector (Zincite/Bornite) is in my experience is much better and more stable.

It is easier to set up in that it is a pressure contact device as opposed to a point contact device so not subject to vibration or not being fiddly to use like the Catswhisker. However I have had very interesting and unusual results by making the Perikon both pressure and point contact by selecting a Zincite crystal with a sharp point. Searching for a spot on the Bornite crystal with the tip of the Zincite crystal in a similar way to the Catswhisker yields some very much higher sensitivity 'sweet spots' and because it is spring loaded it is also stable to vibration. No mention of this has been made in any articles that I have found on the web. Diagrams of Perikon Detectors I have seen on the web are just pressure contact devices with two crystals of about equal size in an adjustable spring loaded device.

My detector has both spring loading and point contact . I use a pointed Zincite crystal of reddish orange and fix it in a tube with a grub screw.I also bind a small piece of pewter which is very soft(Tin alloy) to cushion the crystal against the sides of the tube. The Bornite (or Peacock ore)is similarly held in place in a slightly larger tube or cup. I have experimented with the Woods metal method of securing the crystals but found it to be too messy with molten metal ending up all over the place on the brass turned parts.



Here is a breakdown of my detector into its component parts. There are over 60 simple parts to this device although when assembled looks much less. G W Pickard experimented with many thousands of combinations of crystal. This is a few of the more well known combinations of crystal.

I can custom build you a Perikon detector. Have a look at my detectors page.

Home Page

Aerial Parts | Brass Hardware | Capacitors | Coils | Detectors | Diodes Engraved | Links | Loose Coupler | Misc. Items | Radios |Radios-2 Radios-3 | Switches | Workshop

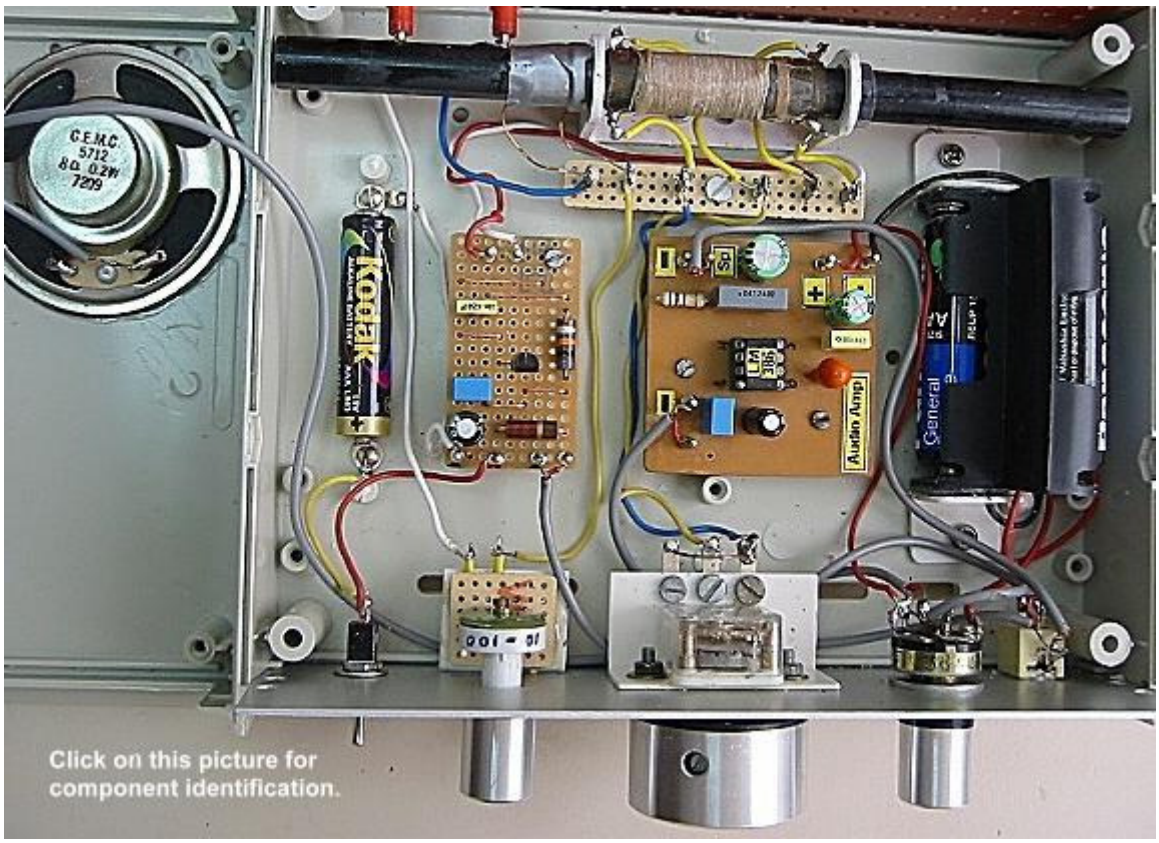
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Build an efficient MW-Receiver with the MK484 & LM 386 ICs



Among the immense amount of modern integrated circuits, now has come to life a new version of the old ZN 414 (developed by Ferranti) which in 1973 and following years was so well known to radio receiver constructors. This new integrated is the MK 484; a three pins chip with the looking of a single transistor, but with nothing more than three radio frequency stages...an automatic gain control-detector-and a high input rating up to 4 meghoms.

If you add to all this that the MK 484 needs only 1,5 volts as a driving voltage, you will understand how attractive is this integrated circuit to build your own radio receiver. I certainly could not resist to experiment with this chip and develop my personal circuit combining its characteristics with an LM 386 IC audio amplifier.

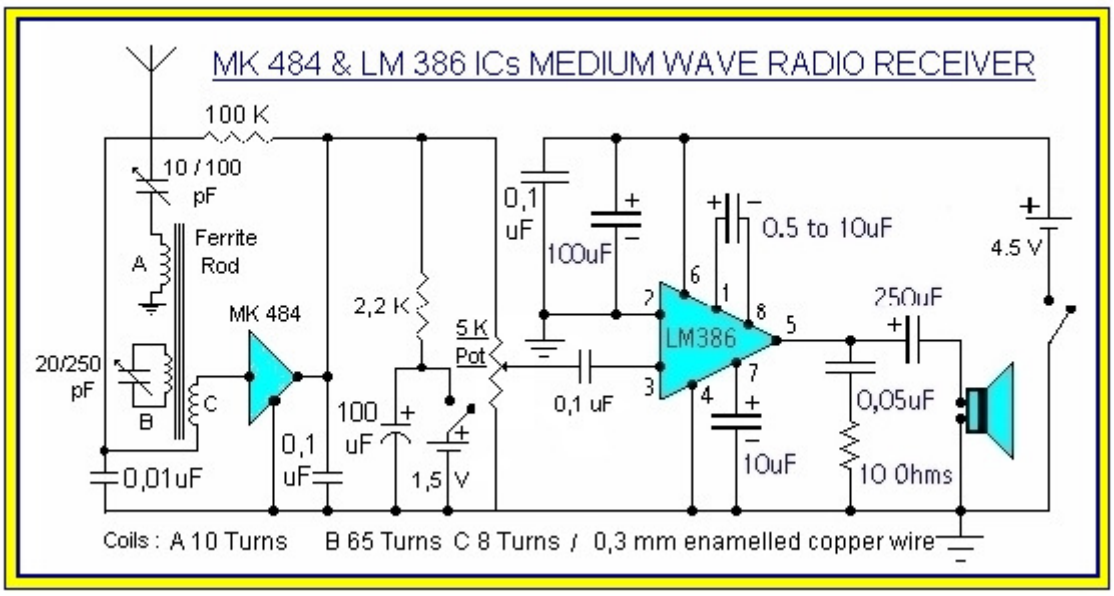


I have made up my project in two modules; one is the MK 484 receiver itself and the other is the audio amplifier.

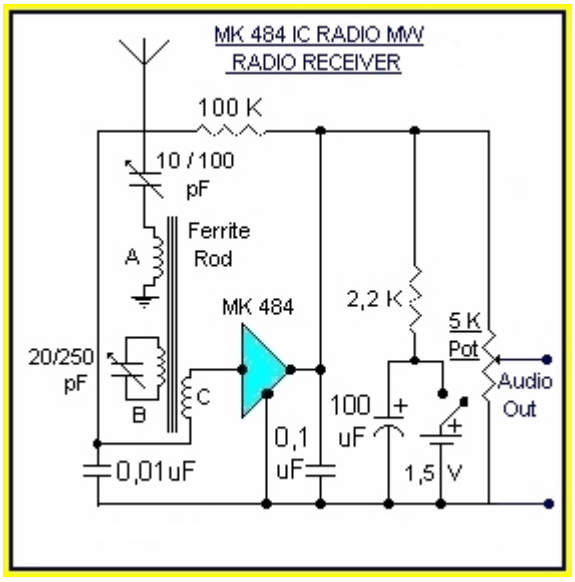
The output of the receiver module is introduced to the LM 386 audio amplifier through a 0,1 uF capacitor after being adjusted by a 5 Kohms potentiometer.

The set has two different power sources; one with 1,5 volts for the receiver and another one with 4,5 volts to the amplifier.

Schematic for the Middle Wave Receiver Using the MK484 and LM386 Integrated Circuits



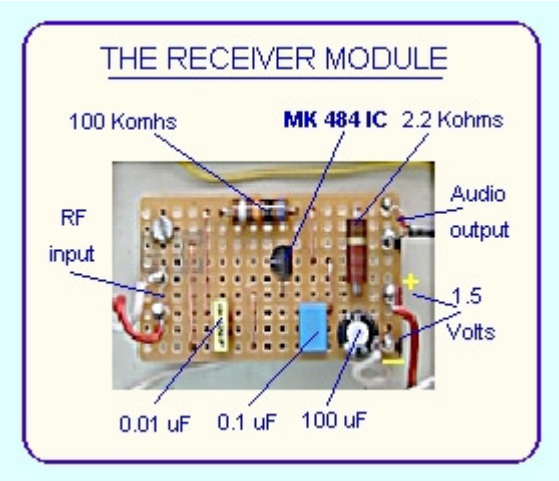
Schematic for the MK484 IC Receiver



You will find on the web some schematics for radio receivers built with the MK 484 IC. In general, all them have a resonant circuit made up of a ferrite rod antenna coil coupled in parallel with a variable capacitor. This resonant circuit is plugged directly to the input of the MK 484 IC. I have tested some of these circuits and found that in spite of the automatic gain control (AGC), when you have a powerful broadcast station near your home, it is difficult to tune other stations of weaker signals...though some improvement can be reached with the ferrite rod directional effect.

We have developed a better circuit using a second coil to the ferrite rod with only a few turns (8 turns) and plugging this coil to the input of the MK 484 IC. With this method we reach a greater selectivity and sensitivity and though a powerful transmitter can overshadow other broadcast stations near to its frequency, the signal of that transmitter disappears when other stations are correctly tuned.

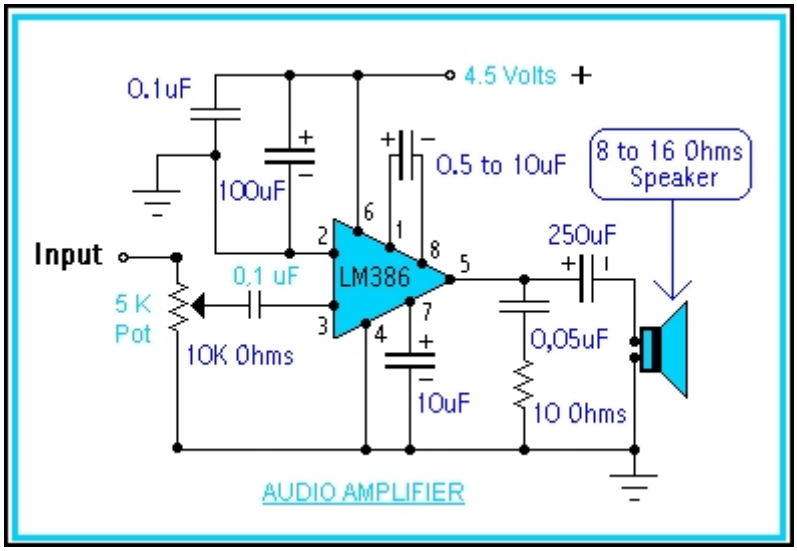
A more improved method is the addition of a third coil, also on the ferrite rod, to facilitate the use of an external antenna, what opens an interesting set of experiments for exploring how we can tune far distant stations. ***Please see the details and values of the components that integrate this receiver in the schematics.***



List of Components Needed for the MK 484 Receiver

Variable Tuning Capacitor (20pf to 250pf)	**100 kohms 1/4 Watt Resistor**
Antenna coupling (Variable Capacitor 10pF to 100pF)	**2.2 kohms 1/4 Watt Resistor**
Ferrite Rod Antenna (Please see text)	**5 kohms Logarithmic Potentiometer**
0.01uF Ceramic or Mylar Capacitor	**1.5 Volt Battery**
0.1uF Ceramic or Mylar Capacitor	**MK 484 Integrated Circuit**
100uF Electrolytic Capacitor	**A Switch**

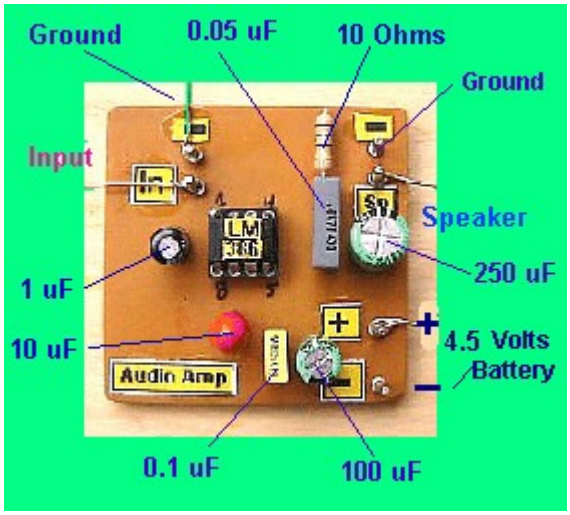
Schematic for the LM386 Audio Amplifier



This receiver can be operated directly with a high impedance earphone, a crystal or ceramic earphone...but adding to its output an audio amplifier makes the set a complete radio receiver able to drive any 8 ohms 0.2 watts speaker.

So you have enough audio power to fill your room. Though if you prefer listening with phones, it is possible to add a plug for inserting any low magnetic phone. The schematics of the audio amplifier is the same as you can find in our pages built with the LM 386 IC on our website...

The only difference is that this audio amplifier is driven with a 4,5 volts battery or three 1.5 volts cells in a series connection.We prefer an independent battery to the audio amplifier to eliminate the risk of an over-voltage to the MK 484 IC in case of a connection error. Please remember that this integrated does not support voltages over 1.8 volts. ***The quality of this audio amplifier meets the standards of any commercial radio receiver.***

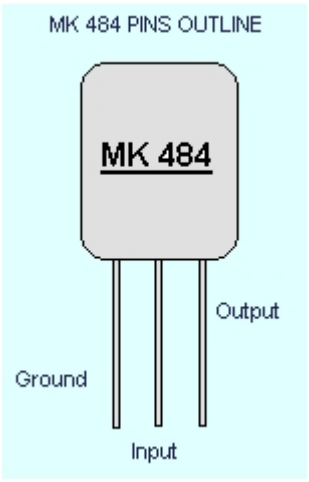


List of Components Needed for the LM386 Audio Amp

0.1uF Ceramic or Mylar Capacitor	**250uF 16 Volt Electrolytic Capacitor**
100uF Electrolytic 16 Volt Capacitor	**8 to 16 Ohms Loudspeaker**
0.1uF Ceramic or Mylar Capacitor	**4.5 Volt Battery**
0.5uF to 10uF Electrolytic 16 Volt Capacaitor	**LM 386 Integrated Circuit**
0.05uF Ceramic or Mylar Capacitor	**A Switch**

MK 484 IC Main Data and Pin Outline

This integrated is quite easy to manage. Its main characteristic is its low feeding voltage...only 1.5 volts. Nevertheless you can drive this integrated from 1.1 to 1.8 volts, but not more than 1.8 volts; higher voltages will destroy the circuit.



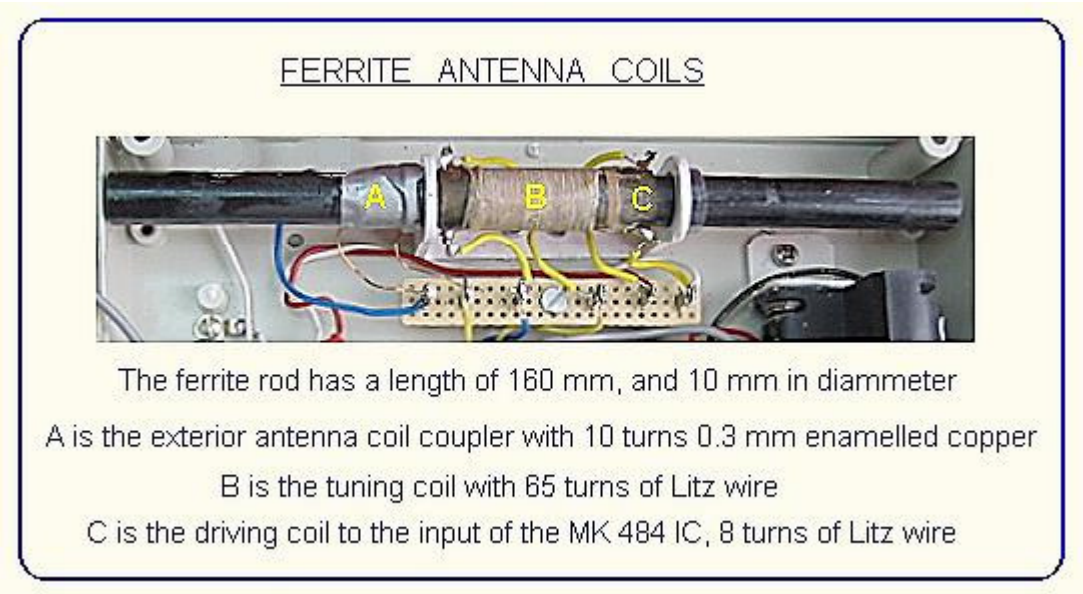
In our project, and to avoid the risk of over-voltages, we have used a separate battery to feed the chip. It is a cell of 1.5 volts with its corresponding switch. The audio amplifier has another independent battery of 4.5 volts that sources enough power to drive an 8 ohms 0.2 W loudspeaker. We have used a special battery for the MK 484 IC due to the fact that the current drawn from the battery, only about 300 microampers (0,003 miliampers), assures an extremely long life for this battery...if you consider that the set will function till its voltage drop to 1.1 volts.

Other attractive characteristics are its 0.8 to 1.5 milivolts output voltage enough to drive an audio amplifier, and its frequency covering range, from 150 KHz up to 3 MHz, as well as the input resistance of 4 Meghoms.With all these you could construct a receiver for the long wave range, the medium wave, and even for the lower short wave band.

The Ferrite Antenna

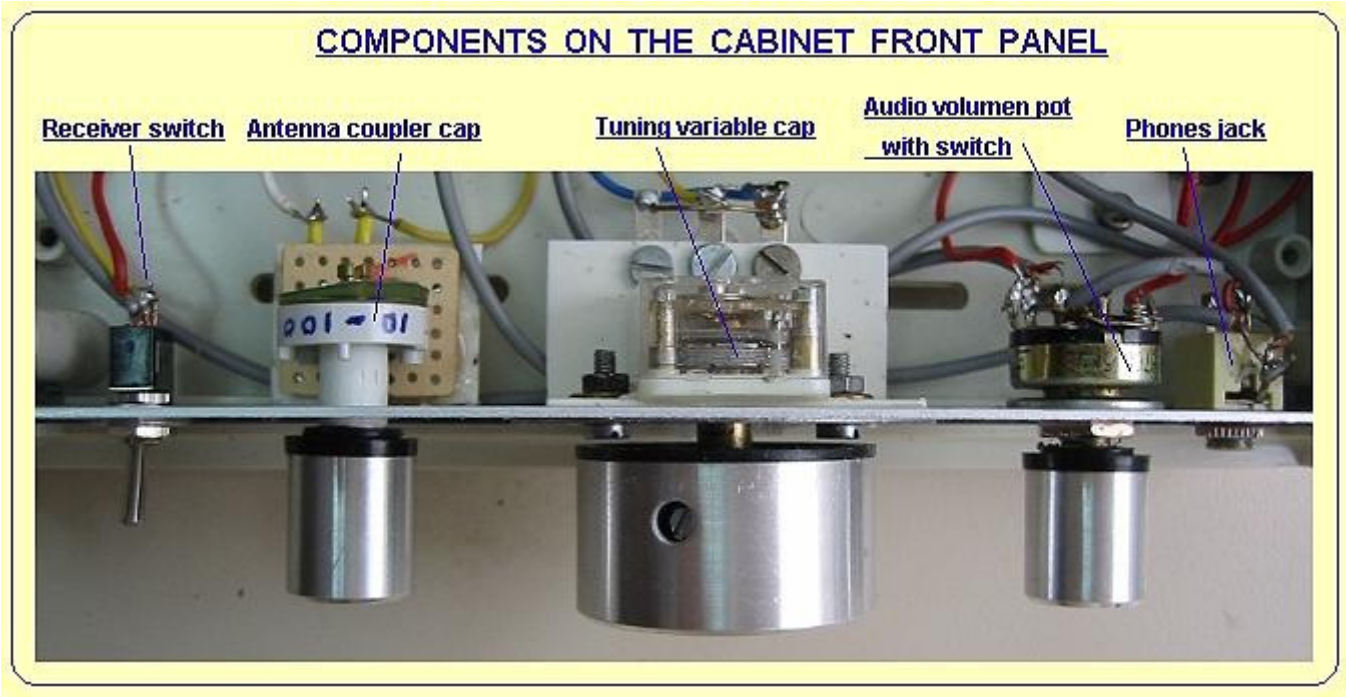
This receiver operates normally with its ferrite antenna and also is provided with a special coil to allow receiving signals from a extenal antenna. This coil has 10 turns of enameled 0.3 mm diameter copper wire. The tuning coil has 65 turns of Litz wire. If you are inspired by this project, let me recommend to you using Litz wire instead of enamelled copper wire.

The coils' quality are superior using Litz wire and in consequence the selectivity and sensitivity of the receiver. Ferrite rod length and diameter are also quite important. Get for your receiver the longest rod you could, and with the bigger diameters as possible. The dimensions in the picture given for the ferrite antenna and coils are not to be follow slavishly...some experimentation on behalf of the constructor will provide the best results.



The Front Panel of the Receiver

Once that the two modules of the receiver are built we have to choose some way of housing them, and all their auxiliary components into a box; if you want to give your receiver a permanent enclosure.



We have situated the external antenna variable capacitor at the left of the front panel; just near the receiver switch. At the right is the volume audio control potentiometer, near a jack for the phones, and in the center is the tuning variable capacitor. At the rear panel of the cabinet are two jacks, one for the exterior antenna and other for ground. Having the main knobs and switches in the front panel is quite easy and a pleasure to command the receiver.



The Cabinet for the MK484 IC Radio Receiver

Any radio receiver driven with a ferrite antenna must be enclosed either in a wooden or a plastic cabinet . Do not use a metallic cabinet for your receiver. Metallic boxes are what is called a Faraday's cage and electromagnetic waves are kept out without reaching the ferrite antennas.



For that reason we have chosen a plastic cabinet with the front and rear metallic panels.



But as the ferrite rod antenna was placed near the rear panel, we have changed this one for a plastic sheet that does not shadow the electromagnetic waves.

Closing words...

The components for this receiver are easy to find at your local electronics shop. Even some items can be taken from discarded commercial transistor radios; such as the variable tuning capacitor and the ferrite antenna rod.

If you have an antenna ferrite rod from a discarded transistor some modification is necessary. The output leads must be separated to identify the leads from the tuning coil which are the two leads that present the higher resistance (about 1.2 ohms) and the two leads for the coupling coil, those with less resistance(about 0.8 ohms). Use the continuity tester and your ohmmeter for this operation.

Finding the MK 484 IC can be a bit more difficult. I got five MK 484 chips from

http://www.bowood-electronics.co.uk/advanced_search_result.php?keywords=MK484&x=0&y=0

at one pound. About $1.50 for each one.

With all the components on your workbench, I wish you happy hours of fun and a complete success with this interesting project !

...your friend, Pedro

RF Energy Harvesting

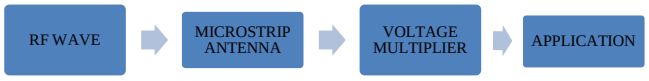
G.VIGNESH, U.VAIRAVAN, P. SUNIL KUMAR & J.SENTHIL,
MS.S.RAJESWARI M.TECH Associate Professor,
Electronics and Communication Engineering.
Saranathan College of Engineering
Trichy - 12, India
gvigneshsekar93@gmail.com,sunilpsk93@gmail.com,Senthiljegatheesan93@gmail.com,vairavan.u@gmail.com

***Abstract*— Electromagnetic energy harvesting holds a promising future for energizing low power electronic devices in wireless communication circuits. This article presents an RF energy harvesting system that can harvest energy from the ambient surroundings radio frequency range of ISM band of 2.4GHz. The main module of system is Microstrip antenna designed using Ansoft HFSS tool. Antenna trainer kit of Scientech was used in which the setup comprises of transmitter and receiver placed at suitable distance. With the help of RF detector voltage range of 80mV is obtained. Further work is going on to boost up the voltage. The harvesting system is aimed to provide an alternative source of energy for energizing low power devices.**

I. Keywords—Rectangular Microstrip antenna, HFSS, Bandwidth, Voltage Multiplier, RF-DC conversion.

II. INTRODUCTION

In recent years the use of wireless devices is growing in many applications like mobile phones or sensor networks. There is an active research area investigating a number of alternative ways to extract energy from the environment and convert it into electrical energy for energizing low power electronic circuits directly or store it for later use. One such energy is from radio frequency. RF Energy harvesting from the ambient will have an important role in the future microelectronic circuits. This work is being carried out by many researchers for the following reasons: i. The energy is freely available in space. ii. Complementing the low power sources used for energizing the low power electronic devices, as an application to green technology. RF energy harvesting from ambient sources have great potential to impact on the cellular phones and portable electronic devices. This concept needs an efficient antenna along with a circuit capable of converting RF signals into DC voltage, so as to replace the need for batteries. The increase in wireless applications has generated an increasing use of batteries. Many research teams are working on the autonomy of the batteries by reducing the consumption of the devices. The rectification

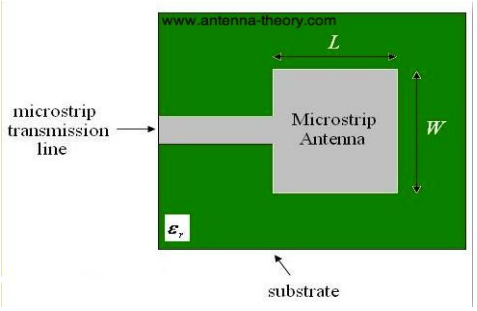


of microwave signals to DC power has been proposed and researched in the context of high-power beaming since the 1950s. It has been proposed for helicopter powering , solar power satellite (SPS) , the SHARP System, and recently for RFID system.. RF sources which are radiating power in all directions all around us. The various sources are DTV, Cell phones, WiFi 802.11b/g(n), WiMax and so on. In an urban environment RF energy is abundant. Utilizing this can reduce the hazards of RF radiations. Vulnerability to these radiations are avoided as they are renewed in terms of power.

III. ENERGY HARVESTING DESIGN SYSTEM.

A. *Atenna Design – Ansoft HFSS Tool.*

Microstrip patch antennas have drawn the attention of researchers over the past few decades.



However, the antennas inherent narrow bandwidth and low gain is one of their major drawbacks . Our antenna is to be designed in the RF range of 2.2 - 3GHz with an resonant frequency of 2.4 GHz.

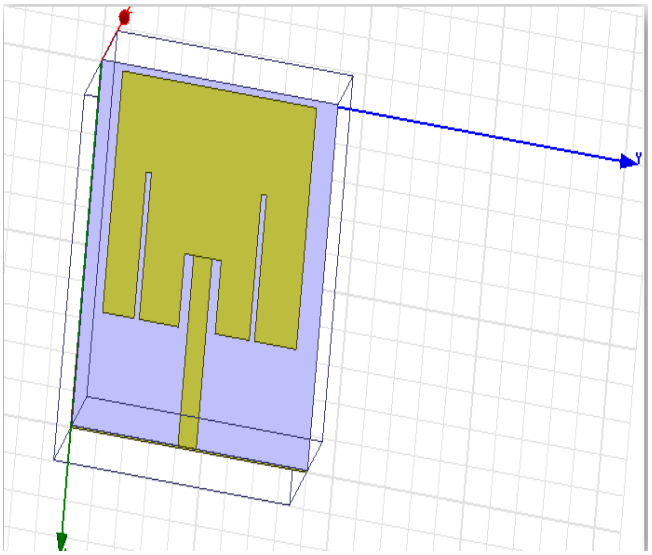
IV. DESIGN EQUATIONS OF ANTENNA

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}$$

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} \qquad L = L_{eff} - 2\Delta L$$

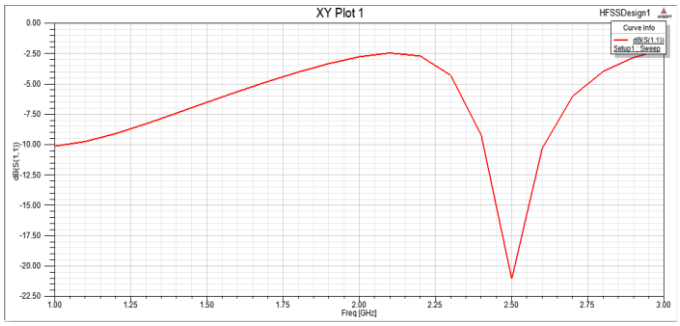


Dimensions of the designed antenna are as follows :

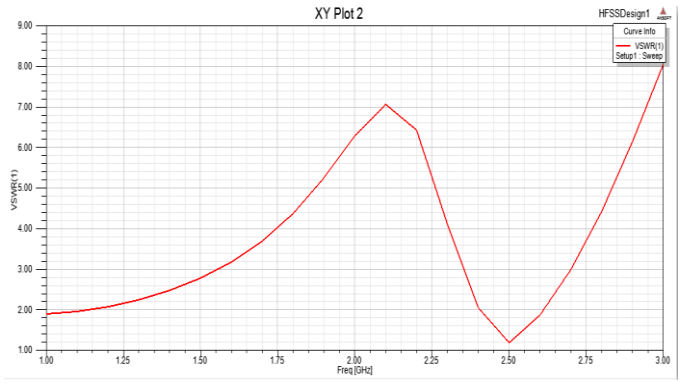
Width = 37mm.
Length = 33 mm.
Feed Line Length = 26 mm.
Feed Line Width = 3.5 mm.
Slot Dimension = 20mm.
Ground = 45*12mm.

We have used partial Ground plane and introduced 2 slots in the patch. The topology of the antenna was designed on a FR4 substrate. It is a grade designation assigned to glass-reinforced epoxy laminate sheets and printed circuit boards (PCBs). This is one of the popular industry-wide standard substrate material format for electronic circuit boards. The key property of FR4 relates to the flame retardant qualities of the material.

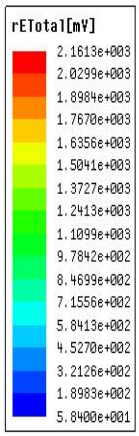
RETURN LOSS :

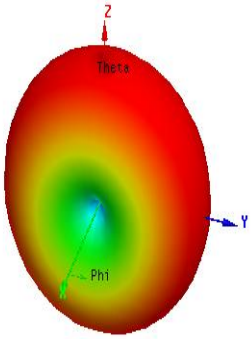


VSWR :



Radiation Pattern



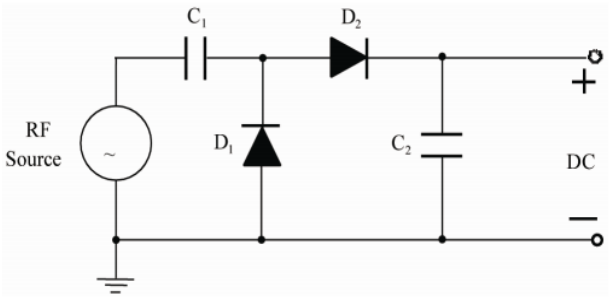


Antenna is designed using High Frequency Structure Simulator by Ansoft. Antenna was designed on FR4 substrate grade designation given to glass-reinforced epoxy laminate sheets and PCB's. The antenna can efficiently capture the energy from ambient RF range of 2.2-3Ghz. Antenna design equations as follows. Antenna size and frequency are related inversely so operating range of GHz will result in miniaturized design. We have obtained the return loss of -22db with an VSWR of 1.2 which is desired result of the antenna.

A. *RF TO DC ENERGY CONVERSION*

The process of converting RF signal to usable form of DC voltage is performed by the Voltage Multiplication Circuit. Rectification occurs here by rectifying the input RF signal. The circuit theory behind voltage multiplier is relatively simple. Each doubler consists of two diodes and two capacitors. At the inital stage of the voltage doubler, the first diode's anode is tied to ground.

As the RF input goes negative, the diode becomes forward biased, allowing charge to flow onto the first capacitor.



Single stage voltage multiplier circuit

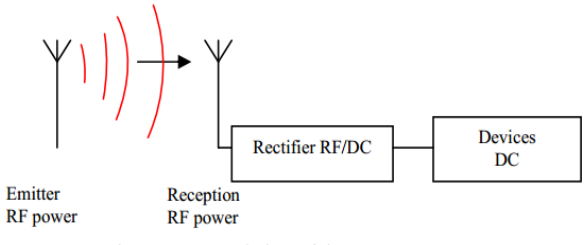
Once the voltage on the first capacitor is high enough, the second diode turns "on" and begins conducting. This current then flows onto the second capacitor,with twice the voltage as the first (assuming no voltage drop across the diode).This comprises one voltage doubler stage. By cascading additional stages, it is possible to further boost the input voltage. In practice, this type of voltage doubler — often called a Cockcroft-Walton generator — has a number of drawbacks.

When the number of cascaded stages is increased, the voltages of the later stages begin to sag, primarily due to the AC impedance of the capacitors in the lower stages. And, when supplying an output current, the voltage ripple rapidly increases as the number of stages is increased. For these reasons, CW multipliers with large number of stages are used only where relatively low output current is required. The most interesting feature of this circuit is that when these stages are connected in series. This method behaves akin to the principle of stacking batteries in series to get more voltage at the output.

The output of the first stage is not exactly pure DC voltage and it is basically an AC signal with a DC offset voltage. This is equivalent to a DC signal superimposed by ripple content. Due to this distinctive feature, succeedingstages in the circuit can get more voltage than the preceding stages. If a second stage is added on top of the first multiplier circuit, the only waveform that the second stage receives is the noise of the first stage. This noise is then doubled and added to the DC voltage of the first stage. Therefore, the more stages that are added, theoretically, more voltage will come from the system regardless of the input.

B. *Feasibilty of Energy Conversion Process*

In order to test the reliability and feasibility in harvesting power from RF a miniature model was designed in the licensed band of GSM 900 MHz with simple lambda/2 wire antenna. The diodes used were fast switching IN4148 and IN4007.



Since used wire antenna can resonate to 0.9Ghz band it can receive the RF energy when source is nearer to it. Most probably the source is cell phone . The wire antenna can receive signals intended for cell phone. With the help of multiplier circuit we were able to improve the convert RF signal into usable DC voltage which power any small device.The observed Voltage range was 4-5volts with a single stage of voltage doubler. As used antenna is omnidirectional placing a source at suitable distance avoiding interference efficiently produces output voltage of 9-10 v with no load conditions. Using 1W LED as load we were able to achieve output of 2Volts.

C. *Harvesting Energy Via Patch*

The most important process is to harvest the energy through the patch antenna so that implementation becomes practically possible.Using Antenna Trainer kit the RF signal is transmitted via transmitting antenna. Antenna Trainer kit used here is Scientech 2261. An input current of 110µA is taken from the kit and it is fed to the transmitting antenna. This current gets converted into RF signals while travelling in the free space as magnetic lines. Both the transmitting and receiving antenna is mounted on a non conducting mast. The receiver antenna used here is patch antenna which captures the RF signal, transmitted from the transmitting antenna. The antennas are separated at a distance of 1 feet. The output of the Patch antenna is given to the RF detector which is also a product of Scientech 2261. RF detector is a test device to detect radio frequency oscillations in electronic circuits.

The Receiver Patch antenna with SMA connector is connected to the RF detector using BNC connector cable. The *BNC* (Bayonet Neill–Concelman) connector is a miniature quick connect/disconnect radio frequency connector used for coaxial cable. **SMA** (*SubMiniature version A*) connectors are semi-precision coaxial RF connectors developed as a minimal connector interface for coaxial cable with a screw type coupling mechanism.

There is some negligible amount of loss occurs during this connection. First 2 element yagi uda antenna is tried on the receiver side and it is connected to the RF detector to measure the output. In the RF detector to measure the output current we need an 9V adaptor. The output DC voltage is measured using multimeter by connecting the multimeter probe to the output knob of RF detector. For this voltage measurement we need not require the 9V adaptor. The output voltage we obtained using 2 element yagi uda antenna is 750mV. While using our designed 2.4 GHz Microstrip antenna we could obtain the output voltage of 80mV.

V. FUTURE WORK

Inorder to obtain a considerable amount of voltage for wireless applications we were working to boost up the received voltage at the current stage.

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Pacific Antenna SLT+ Switched Long wire Tuner

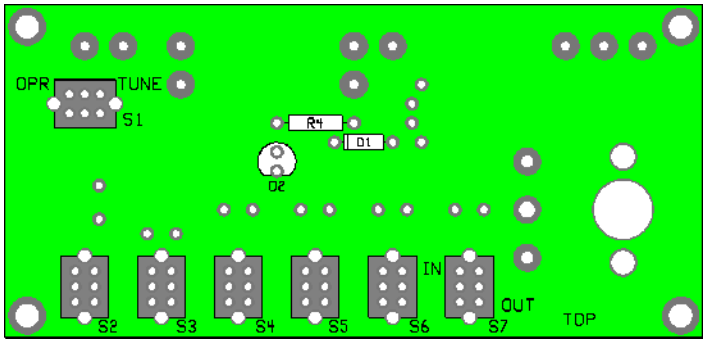


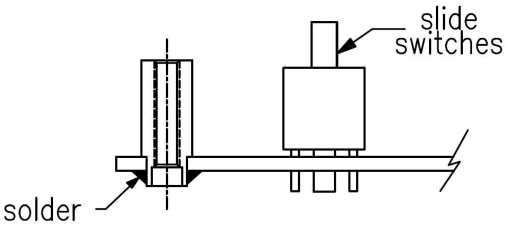
The SLT+ is designed to match the high impedance load of an end feed, half wave antenna wire to a 50 ohm transmitter using manually switched inductors and a variable capacitor configured in a “L” matching network. Six inductors in BCD weighted values allows for selecting inductor values from 0.5 uHy to 23.5 uHy in 0.5 uHy steps. A resistive SWR bridge with LED indicator is built in so an external SWR bridge is not required to find the match. This tuner and end feed antennas are ideal for field operation of QRP rigs.

Parts list:		
Quantity	Designation	Value/ description
1	Circuit board	
7	S1-8	DPDT slide switches
3	R1,R2,R3	51 ohm, 2W resistors
1	R4	470 ohm 1/4W resistor
1	D1	SD101 diode
1	LED	Clear, ultra bright LED
1	T1	FT37-43 ferrite core (black)
2	L1 ,L2	T50-2 RED toroid core (large)
4	L3,4,5,6	T37-2 RED toroid core (small)
1	C1/C2	Poly-variable tuning cap
1 set		Knob, 3 screws, and nylon spacer for poly-varicon.
8 feet		Red #28 magnet wire
9”		Green #28 magnet wire
1		Red 5 way binding post
1		Black 5 way binding post
1		BNC jack
4		3/16” Swage board standoff, #2
4		1/4” #2 flat head screws
1		Case
		Set of decals

Construction:

Parts are mounted to both the top and bottom side of the circuit board. We will start with the top side.

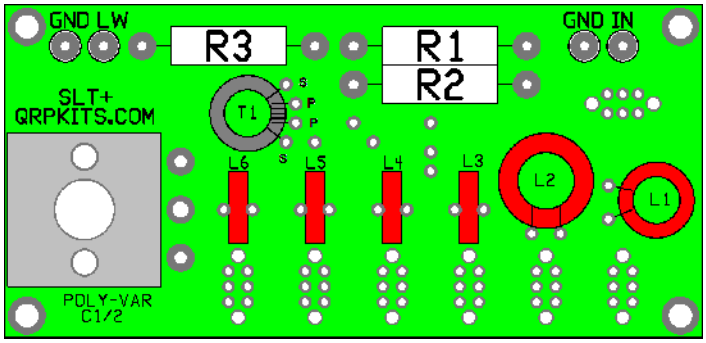




Install standoffs on topside of the board, and solder on bottom side.

1. Install the four (4) 0.187” Swag standoffs into the four mounting holes in the corners of the board. These are inserted from the **TOP SIDE** of the board. Run a bead of solder around the outside edge of the standoffs sticking out the **BOTTOM** of the board to attach them to the solder pad around them. You will need a fairly high wattage iron to do this.
2. Install the seven (7) DPDT slide switches on the top side of the board.
3. Install R4, 470 ohm resistor (Yellow, Violet, Brown, Gold)
4. Install D1, SD101 glass diode
5. Install the LED. Be sure to match up the flat on one side of the LED package with the flat side of the LED outline on the board. Do not mount the LED flush to the board. With the board flipped over so that you can solder the leads, let the top of the LED touch your work bench so that it is the same height as the top of the switch levers.

Bottom side of board:



1. Wind and install T1. Wind the 25 turn secondary first (16” of red wire) on the BLACK T37-43 ferrite core. Then wind the 5 turn (9” of green wire) primary in the gap between the secondary turns. See illustration on next page. The leads from the secondary winding go into the top and bottom holes labeled “S” in the diagram and the primary winding leads into the middle holes labeled “P” Be sure to tin the wire ends before trying to solder the wires to the pads on the board. The insulation can be melted through with a hot soldering iron with a blob of solder on the tip and rubbing the wire until the insulation melts. Or, the insulation can be burnt off with a match or lighter, then cleaned up with some fine grit sandpaper or emery cloth.
2. Install R1, R2 and R3 the 51 ohm (Green, Brown, Black, Gold) 2 watt resistors
3. Wind and install L1 and L2. (See table next page for number of turns) These both mount flat to the board. L1 will overhang the edge of the board slightly.
4. Wind and install L3 to L6. These mount vertically on the board.

5. Install the variable capacitor and secure to the board with the two mounting screws. Set the trimmers on the bottom of the cap to minimum setting. (fully unmeshed)

Winding	Table	
L1/L2	T50-2	40 turns (28”)
L3	T37-2	32 turns (18”)
L4	T37-2	22 turns (13”)
L5	T37-2	16 turns (11”)
L6	T37-2	11 turns (8”)

Remember that one turn is each time the wire passes through the center of the core. Evenly space turns around core. Be sure to tin wire ends before soldering to board.

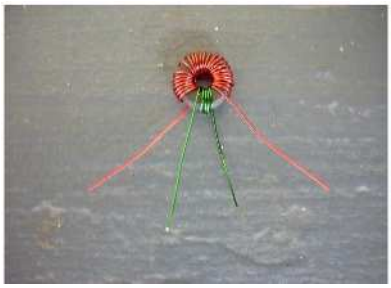


Illustration 1: T1 winding

This competes assembly of the board.

Preparing the case:

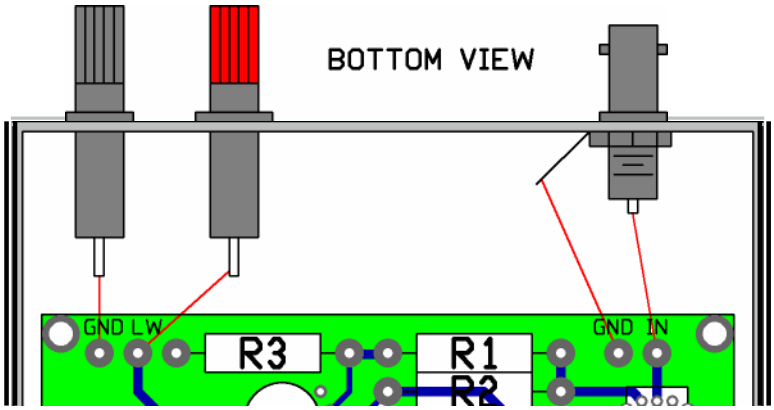
If you like, you can paint the case the color of your choice.

Apply the decals to the case as shown in the picture on page 1 of the manual.

Install the BNC jack and binding posts to the side of the case.

Drop the circuit board into the top of the case and mount using four (4) #2 screws into the standoffs from the top of the case.

Using the resistor lead clippings, jumper the connections from the board to the BNC jack and binding posts.



Pad labeled “IN” goes to the center pin of the BNC jack. Pad labeled “GND” goes to the ground lug on the BNC jack

Pad labeled “LW” goes to RED binding post. Pad labeled “GND” goes to the BLACK binding post

Put bottom cover on case.

Install the nylon spacer and screw onto the tuning capacitor to form a shaft for the knob. A drop of nail polish or super glue on the threads where the screw goes into the cap will help it from becoming loose. Put the knob on the shaft and your are done!

Using the SLT+

For best results, random wire lengths should be avoided. Ideally, the wire length should be about 10% shorter than a 1/2 wave on the band you wish to operate on. An exact 1/2 wave length antenna has a fairly high impedance on the end, which the SLT+ may not be able to match. Making the wire slightly shorter reduces the impedance to something the SLT+ will have an easier time matching. For bands which are harmonically related, a single length of wire will work on these bands. For example, a 1/2 wire on 40 will work as a full wave on 20.

A counter pose wire is recommended. Using a counter pose wire will eliminate any hand capacitance effects which can change the tuning when you remove your hand from the tuner box or rig. The counter pose wire would connect to the ground (black) binding post. Ideally, a 1/4 wave length wire would be used, but good results can be obtained with shorter wires. Lay this wire on the ground and if possible, in a direction opposite the active antenna wire.

The table below shows the approximate value of inductance and capacitance needed to match a wire on different bands. Preset the switches to these values for the band in use and tweak from there. Place the TUNE / OPER switch in the TUNE position to active the SWR bridge. Adjust the tuning capacitor and inductance in order to make the LED dim as much as possible or make it go out all together (best match). Once the match is found, switch back to the OPER (operate) position and start making QSOs!

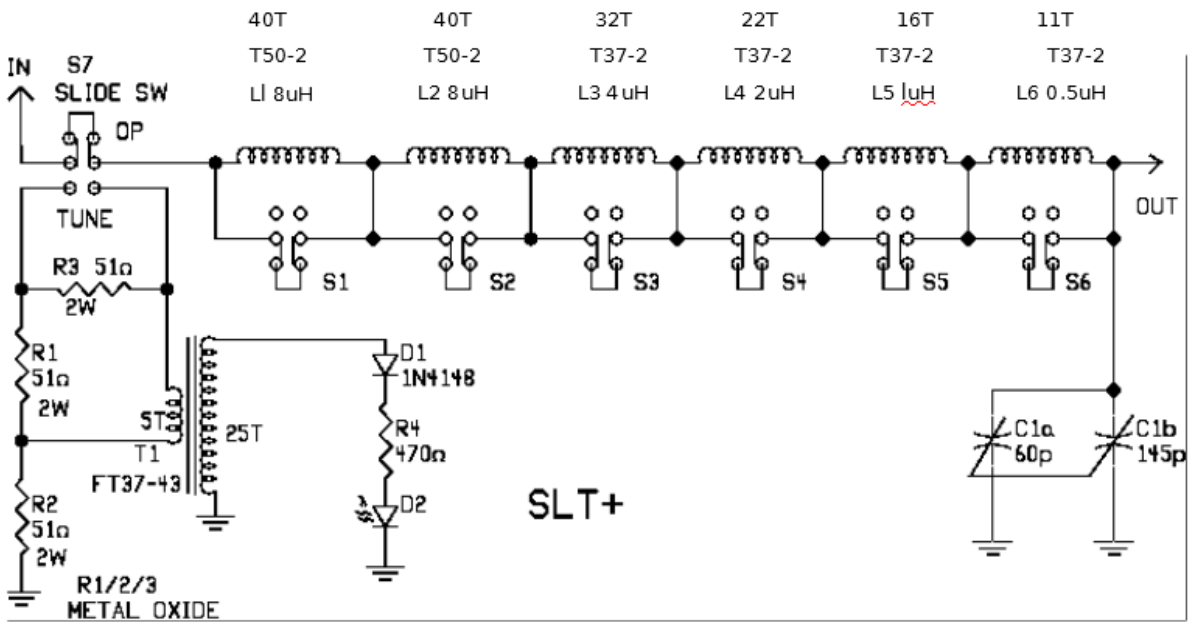
80 M	40 M	30 M	20 M	15 M	10 M
22 uH	12 uH	8 uH	5.5 uH	4 uH	3 uH
100 p	50 p	30 p	25 p	15 p	10 p
Inductor values for switches in “IN” position.					
S1	S2	S3	S4	S5	S6
8 uH	8 uH	4 uH	2 uH	1 uH	0.5 uH

Getting a wire up into the trees:

One of the big advantages of an end feed antenna is the ease and speed it can be erected, compared to dipoles, since only one end of the wire needs to be thrown into the tree. You don't have to find two trees the right distance apart and nothing in between them which would make stretching a wire between them difficult.

The simplest way to get a wire over a tree branch well up off the ground is to use a plastic water or soda bottle 1/3d to 1/2 full of water as a throwing weight. The shape of the bottle is such that it is easy to hold and it slips down between tree branches without snagging or wrapping around branches and getting snagged. Nylon “Mason line” is used as a leader. Simply put one end of the mason line into the top of the bottle and replace the cap. Loosely lay out the line on the ground in such a manner that it will not snag on stuff which might be on the ground. An underhand toss of the bottle is generally the best way to throw it. With a little practice, you should be able to get it at least 20 feet up.

How the wire is configured depends greatly with what you have to work with in terms of support trees. The simplest configuration is an inverted “V” where the wire runs from the tuner, up to a tree branch and back down towards the ground. An “L” configuration is somewhat better for DX, especially if you can get the part of the wire from the tuner up to the tree as vertical and as long as possible. If the wire is run fairly close and parallel to ground, this is good for close in contacts.



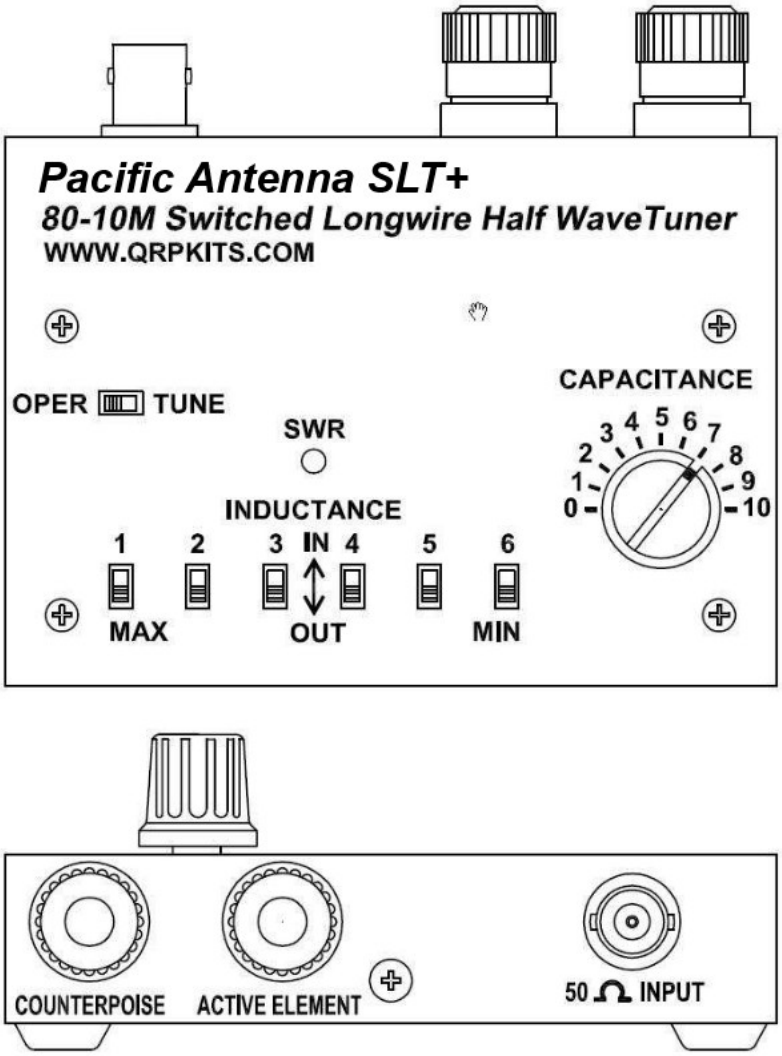
Antenna approximations for CW portion of the bands

Band	80m	40m	30m	20m	17m	15m	10m
Active Ele.	124 ft.	63 ft.	44 ft.	31.5 ft.	24.5 ft.	21 ft.	15.5 ft.
Counterpoise	69 ft.	35 ft.	24 ft.	17.5 ft.	13.5 ft.	11.5 ft	8.5 ft.
Inductance	S 1,2,3,4	S 1,3	S 1	S 3,5,6	S 3	S 3	S 4,5

Counterpoise should be 180° from active element direction

For best results, use as little inductance as possible, to obtain a match. How the wire is configured depends greatly with what you have to work with in terms of support trees. The simplest configuration is an inverted "V" where the wire runs from the tuner, up to a tree branch and back down towards the ground. An "L" configuration is somewhat better for DX, especially if you can get the part of the wire from the tuner up to the tree as vertical and as long as possible. If the wire is run fairly close and parallel to the ground, this is good for close in contacts.

If you desire, print this out, seal with clear packaging tape, and apply to the bottom of the tuner with two-sided tape for a reminder.



Pacific Antenna SLT + Decal Installation

The decals are applied the same as model decals. Cut around each group of text or symbols you wish to apply, leave a border. It doesn't have to be perfect as the background film is transparent. Apply the decals before you mount anything to the cover. Use the above 1:1 picture to get the correct spacing around the holes, as it is very easy to do a great decal installation and have a portion covered up with a knob. Use the cross in the center of the capacitance group, and center it in the hole

Thoroughly clean the surface of the panel to remove any oils or contamination.

Trim around the decal, leaving about 1/16" space around the printing. After trimming place the decal in a bowl of lukewarm water, with a small drop of dish soap to reduce the surface tension, for 10-15 seconds. Handle carefully to avoid tearing. Start to slide the decal off to the side of the backing paper, and place the unsupported edge of the decal close to the final location. Hold the edge of the decal against the panel, with your finger, and slide the paper out from under the decal. You can slide the decal around to the right position, as it will float slightly on the film of water. Use a knife point or something sharp to do this. When in position, hold the edge of the decal with your finger and gently squeege excess water out from under the decal with a tissue or paper towel. Work from the center, to both sides. Remove any bubbles by wiping gently to the sides. Do this for each decal, and take your time. Allow to set overnight, or speed drying by placing near a fan for a few of hours. When dry, spray two light coats of matte finish, Krylon, clear to seal and protect the decals, and allow to dry in between coats. All decals come with two complete sets, in case you mess one up.

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Plus Shape Slotted Fractal Antenna for Wireless Applications

S. Jagadeesha[1], R. M. Vani[2], P. V. Hunagund[3]

[1]S.D.M. Institute of Technology, Ujire Mangalore, India; [2]University Science Instrumentation Center, Gulbarga University, Gulbarga, India; [3]Department of PG Studies and Research in Applied Electronics, Gulbarga University, Gulbarga, India.
Email: Jagadeesh.sd69@gmail.com, vanirm12@rediffmail.com, prbhakar_hunagund@yahoomail.com

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ABSTRACT

Fractal antennas are characterized by space filling and self-similarity properties which results in considerable size reduction and multiband operation as compared to conventional microstrip antenna. This paper outlines a multiband antenna design based on fractal concepts. Fractal antennas show multiband behavior due to self-similarity in their structure. The plus shaped fractal antenna has been designed on a substrate of dielectric constant ϵ_r = 4.4 and thickness 1.6 mm. The proposed antenna is characterized by a compact size and it is microstrip feed fractal patch of order 1/3. It is observed that the antenna is radiating at multiple resonant frequencies. The resonant frequency is reduced from 2.2 GHz to 900 MHz after I & II iterations respectively. Thus considerable size reduction of 81.77% & overall bandwidth of 12.92% are achieved. The proposed antenna is simulated using the method of moment based commercial software (IE3D) and it is found that simulated results are in good agreement with the experimental results.

Keywords: Fractal Antenna; Multi Frequency; Size Reduction; Wireless Application; Plus Shape Antenna; Slotted Antenna

1. Introduction

In the study of antennas, fractal antenna theory is a relatively new area. The emergence of antennas with fractal geometries has given an answer to two of the main limitations started by Werner (1999) of the classical antennas, which are single band performance and dependence between size and operating frequency. The term "fractal" means broken or irregular fragments. It was originally coined by Mandelbrot (1983) to describe a family of complex shapes that possess an inherent self-similarity or self-affinity in their geometrical structure. Jaggered (1990) defined fractal electrodynamics as an area in which fractal geometry was combined with electromagnetic theory for the purpose of investigating a new class of radiation, propagation and scattering problems. One of the most promising area fractal electrodynamics researches is in its application to antenna theory and design. There are varieties of approaches that have been developed over the years, which can be utilized to archive one or more of these design objectives. The development of fractal geometry came largely from an in depth study of the pattern nature, with the advance of wireless communication system and their increasing importance wide band and low profile antennas are in great demand for both commercial and military applications [1]. A fractal is a rough or fragmented geometric shape that can be split into parts, each of which is a reduced-size copy of the whole and this property is called self-similarity. Fractal [2] geometries are composite designs that repeat themselves or their statistical characteristics and are thus "self-similar" fractal geometry finds a variety of applications in engineering. Fractal geometry is space filling contours of regular or irregular shapes [3-6], and is super imposed of too much iteration and they describe the self-similar property of fractal geometry [7]. Fractals are a class of shapes which have not characteristic size. Each fractal is composed of multiple iterations of a single elementary shape the iteration can continue infinitely, thus forming a shape within a finite boundary but of infinite length or area. Fractal has the following features 1) It has a finite structure at arbitrarily small scales; 2) It is too irregular to be easily described in traditional Euclidean geometric; 3) It is self-similar; 4) Simple and recursive [8]. Modern telecommunication systems require the antenna with wider bandwidth and smaller dimension than conventionally possible. This has initiated antenna research in various directions, are of which is by using fractal shaped antenna elements. In recent years several fractal geometries have been introduced for antenna application with varying degree of success in improving antenna

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characteristics. Some of these geometries have been particularly useful in reducing the size of the antenna, while other designs aim at incorporating multiband characteristics. These are low profile antennas with moderate gain and can be made operative at multiple frequency bands and hence are multifunctional [9]. In our present work we focus on generation of multifrequency which yields increases the bandwidth and size reduction of antenna. A plus shape patch is taken as a base shape and in first iteration four other plus shape patches of the order of 1/3 of base shape are placed touching the base shape. Similarly second iterations are taken by further placing plus shaped patches at even reduced scales. It is found that as the iteration number and iteration factor increases, the resonance frequencies become lower than those of the zero iteration, which represents a conventional plus shape patch.

2. Design Consideration

The base shape of the plus shaped slotted fractal antenna is designed on a dielectric substrate having a relative dielectric constant €$_r$ = 4.4 and thickness 1.6 mm as shown in **Figure 1**. This is the reference antenna or base shape antenna. Further this base shape antenna is modified by inserting horizontal slots on both sides with respect to center of patch as shown in **Figure 2** and it is named as antenna1. The length of the slot Ls is varied on either side of the edge as 5 mm, 10 mm, 15 mm, 20 mm, 21.175 mm, 21.675 mm and the frequency variation has been studied. The optimum length obtained is Ls = 21.675 mm *i.e.*, the distance between slots q = 2 mm is considered for further design.

The first iteration patch is designed with four plus shapes of order (1/3) of base shape are placed touching the base shape as shown in **Figure 3** and it is named as antenna 2 and same procedure is repeated for second iteration. This antenna is as shown in **Figure 4** and it is named as antenna 3. For each iteration plus shapes of the order of $(1/3)^n$ of base shape are taken, where n is the number of iterations. The dimension of first iteration can be calculated as

e = (1/3) a & g = (1/3) c also f = (1/3) b & h = (1/3) d.

i = (1/3) e & k = (1/3) g also j = (1/3) f & L = (1/3) h

So with optimized design the dimensions obtained are a = 45.3 mm, b = 15.1 mm, c = 35.4 mm, d = 11.8 mm. The length of the slot is Ls = 21.675 mm and width of the slot Ws *i.e.* r = 2 mm. The dimension of the ground plan is 55 mm × 85 mm. A 50 ohm SMA connector is used to feed the antenna by using microstrip feed technique. Optimized microstripline with following dimension, m = 0.5 mm, n = 18.55 mm, o = 3.05 mm, p = 18.4 mm. The suitable feed location is obtained through optimization process by using the IE3D software. The fabric

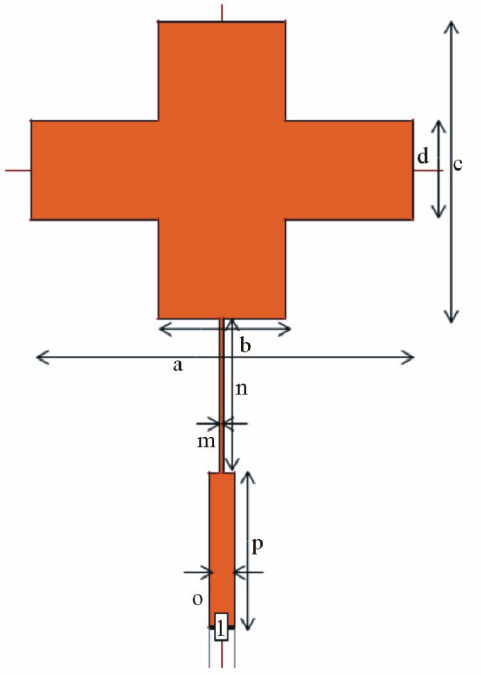


Figure 1. Geometry of base antenna.

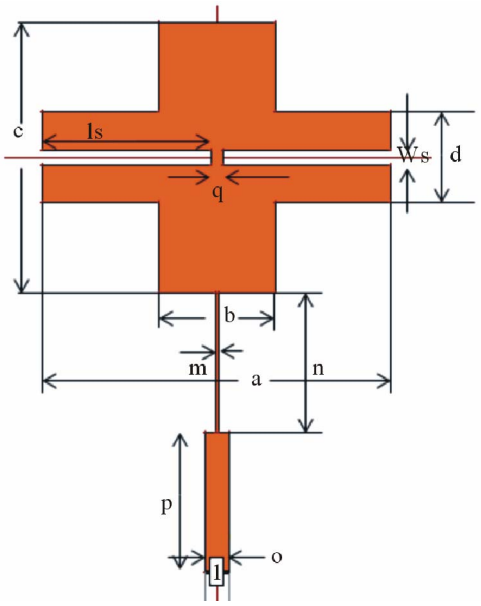


Figure 2. Geometry of antenna 1.

cated photographic view of all proposed antennas is shown from **Figures 5(a)-(e)**.

3. Results and Discussion

The characteristic of the fractal antenna with slot and with iterations has been studied by using IE3D software. Also the results have been verified practically with by using Vector Network Analyzer model Rohde and schewarz, German make ZVK model No.8651.

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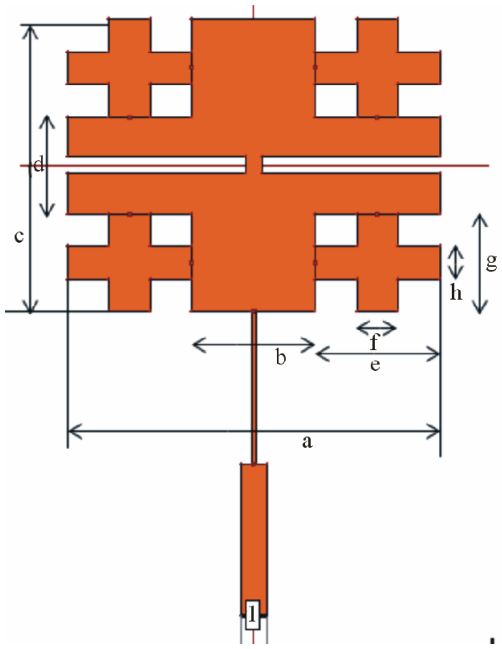


Figure 3. Geometry of base antenna 2.

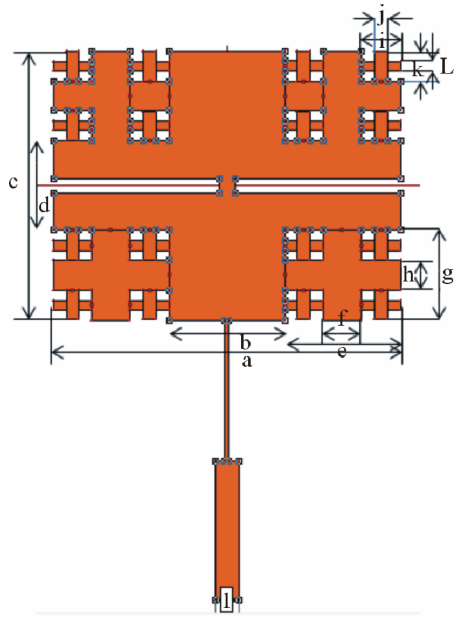
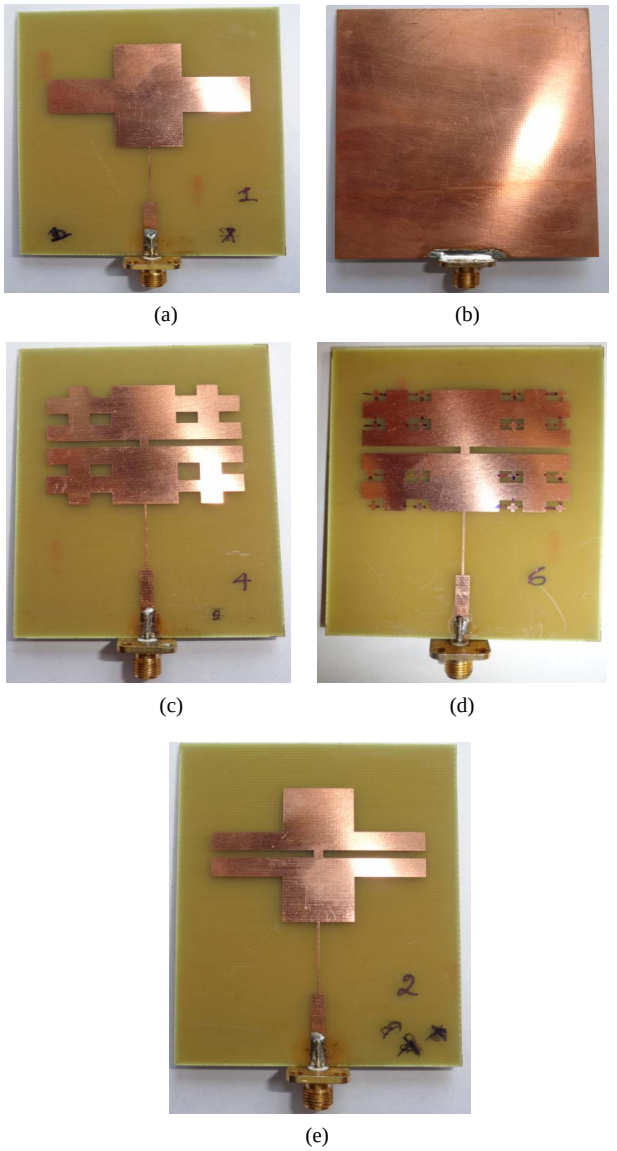


Figure 4. Geometry of antenna 3.

The modified base shape antenna with slots as been optimized by varying slot length Ls. The variation of Ls with resonant frequency of the antenna is shown in **Table 1** and same is presented in graphical form in **Figure 6**. From the tabular results it is found that by increasing slot length Ls on both sides from the edge of the patch, resonant frequency decreases. The lowest possible resonant frequency 1.27 GHz is obtained for Ls = 21.675 mm (*i.e.*, distance between the slots q = 2 mm) & this is taken as optimized length of the slot for further iteration.

The results of all proposed antennas are shown in **Table 2**. The simulated and measured return loss characteristics of proposed antennas are shown from **Figures 7(a)-(d)**.

From the results it is clear that the resonant frequency of the antenna 1 *i.e.*, modified base antenna with slot is fr = 1.27 GHz which is lower compared to the base antenna without slot (fr = 2.199 GHz). So the size reduction obtained is 66.85%. The antenna 2 *i.e.* the modified antenna with slots and first iteration gives multiple bands with lower frequency of 0.99 GHz. The size reduction obtained for antenna 2 is 79.88%. Further antenna 3 *i.e.*, with slot and second iteration gives multiple bands with



(a) (b)

(c) (d)

(e)

Figure 5. (a) Photograph of top view of base antenna; (b) Photograph of bottom view of base antenna; (c) Photograph of antenna 1; (d) Photograph of antenna 2; (e) Photograph of antenna 3.

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Table 1. Variation of slot length v/s resonant frequency.

Slot length (Ls) variation in mm	Resonating frequency (GHz)
0	2.22
5	2.197
10	2.155
15	1.93
20	1.436
12.175	1.34
21.675	1.27

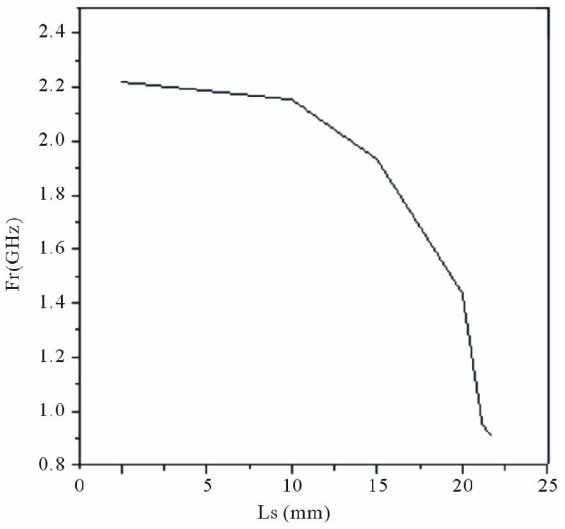


Figure 6. Variation of resonant frequency v/s slot length.

lower resonant frequency of 0.90 GHz. The size reduction obtained for antenna 3 is 81.77% which is more compared to all other proposed antennas.

Further the bandwidths of proposed antennas have been studied through simulation and measurements and the results are shown in **Table 2**. From the results it is clear that the bandwidths of modified antenna with slot, first & second iteration are more compared to base antenna. The measured bandwidth of antenna 1 is 106 MHz (4.895%), antenna 2 is 190 MHz (11.93%) and antenna 3 is 215 MHz (12.92%). The radiation patterns of all proposed antennas are studied and all are giving broadside radiation. Splitting of beam *i.e*. dip is found in **Figure 8(a)** of simulated radiation pattern of base shape at 2.19 GHz. In **Figure 8(b)** splitting of beams merged into broadside pattern at 0.91 GHz at second iterations this results into broadside radiation pattern.

4. Conclusion

This paper presents a new plus shape slotted fractal antenna with first and second iterations. The antenna.3 *i.e*., slotted fractal antenna with second iteration gives size reduction of 81.77% and band width of 12.92% with broad side radiation pattern. So from the results we conclude that the modified base antenna with slots of second iterations gives a good size reduction and enhanced band width compared to that of modified base antenna with

Table 2. Results of proposed antennas.

Prototype antenna	Resonant frequency fr (GHz)		Return loss (db)		Bandwidth (MHz)		Overall bandwidth (MHz)	
	Sim	Pract	Sim	Pract	Sim	Pract	Sim	Pract
Base antenna	f1 – 2.19	f1 ± 2.19	–19	–24	53	53	79	71
	f2 – 3.42	f2 ± 2.46	–14	–15	26	18		
Antennal with q = 2 mm	f1 ± 1.19	f1 ± 1.27	15.8	–12.8	20	18		
	f2 ± 2.52	f2 ± 2.48	18.4	–20.1	113	44	133	106
		f3 ± 2.56		–18.7		44		
Antennal 2 with q = 2 mm (1st itr)	f1 ± 0.96	f1 ± 0.99	16.7	–14.5	22	80		
	f2 ± 2.9	f2 ± 2.97	–14	–26.9	44	50	136	190
	f3 ± 3.08	f3 ± 3.17	21.5	–21	70	60		
Antennal 3 with q = 2 mm (2nd itr)	f1 ± 0.91	f1 ± 0.990	15.2	–14.2	11	87		
	f2 ± 3.07	f2 ± 2.976	19.4	–17.6	70	50	81	215
		f3 ± 3.168		–18.9		78		

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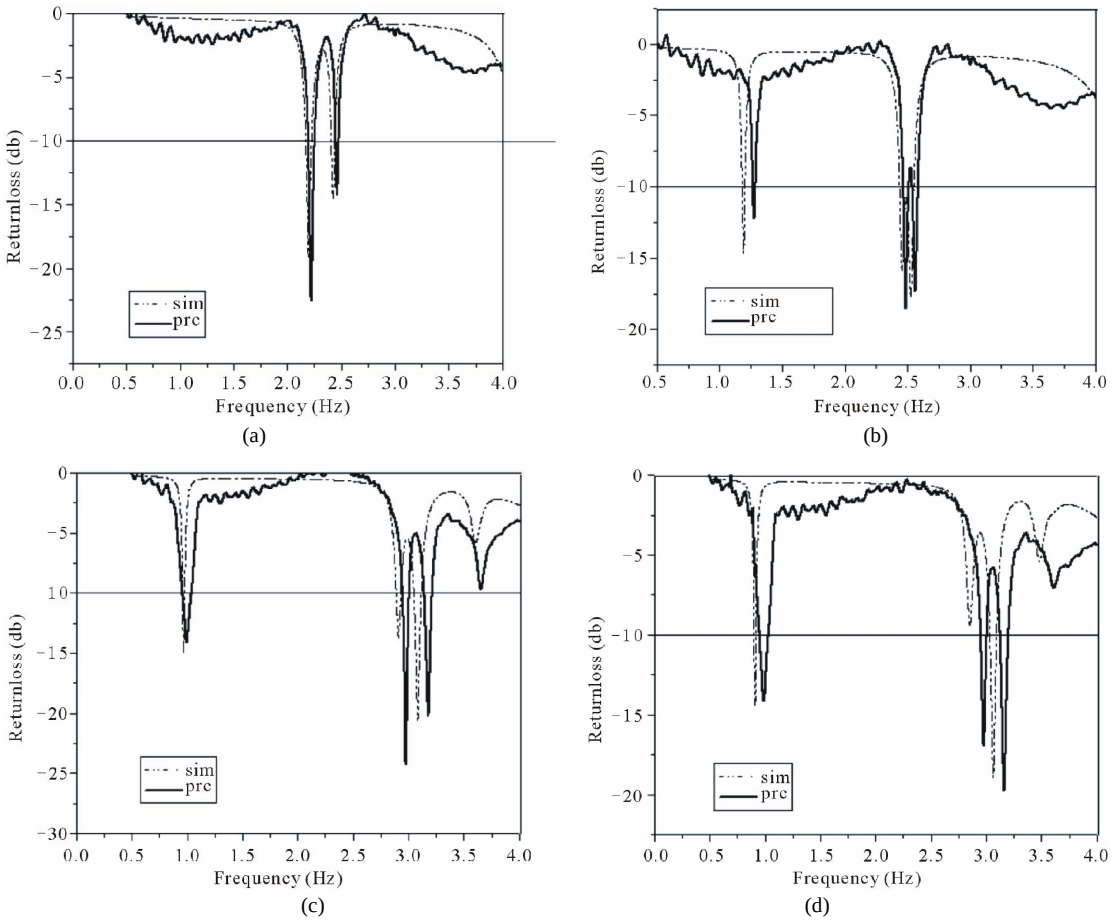


Figure 7. (a) Return loss characteristic of antenna 1 with q = 2 mm; (b) Return loss characteristic of base antenna 2 with q = 2 mm; (c) Return loss characteristic of antenna 2 with q = 2 mm; (d) Return loss characteristic of antenna 3 with q = 2 mm.

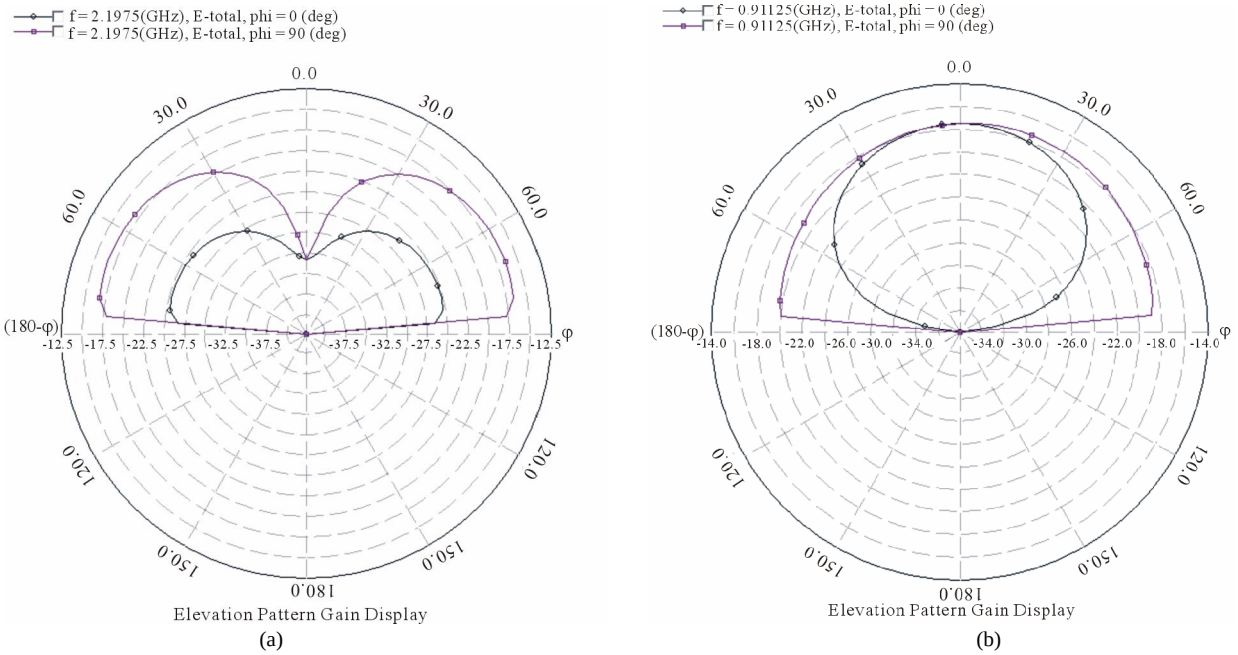


Figure 8. (a) Simulated radiation pattern of base shape at 2.19 GHz; (b) Simulated radiation pattern at 0.91 GHz for second iteration.

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slot of first iteration. These antennas may find application in wireless communication systems.

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DIY Audio Home

The "Engineer's Amplifier" - a distortion canceling push-pull amp using cheap TV tubes (!)

(Note that the photos are hyperlinked to full-size photos in grisly detail)



I am selling PCB's for this project. See my eBay store (seller "pmillett"). $50 each (hey, it's a big PCB!)

And now for something completely different...

The last power amplifier design I published, "The Unnecessarily Complex 300B Amplifier", was a trendy single-ended DHT amp using mercury rectifiers with a choke-input filter, interstage transformers, point-to-point wiring, and all the "audiophile wisdom" I could garner. Sort of an "artist's amplifier".

This is about as opposite a design as can be. It's a push-pull pentode amp, using sweep tubes for the output and pentodes for the input. The power supply uses silicon rectifiers and MOSFET filters and regulators. There is even (God forbid!) some silicon in the driver. And the whole thing is built on a giant bright red PC board. So I decided I should call this one the "engineer's amplifier".

As you might guess, this amplifier measures - and sounds - much different. And it can be built by a fairly inexperienced builder for about $350 total in parts. That's about what the interstage transformers by themselves cost for the last amp!

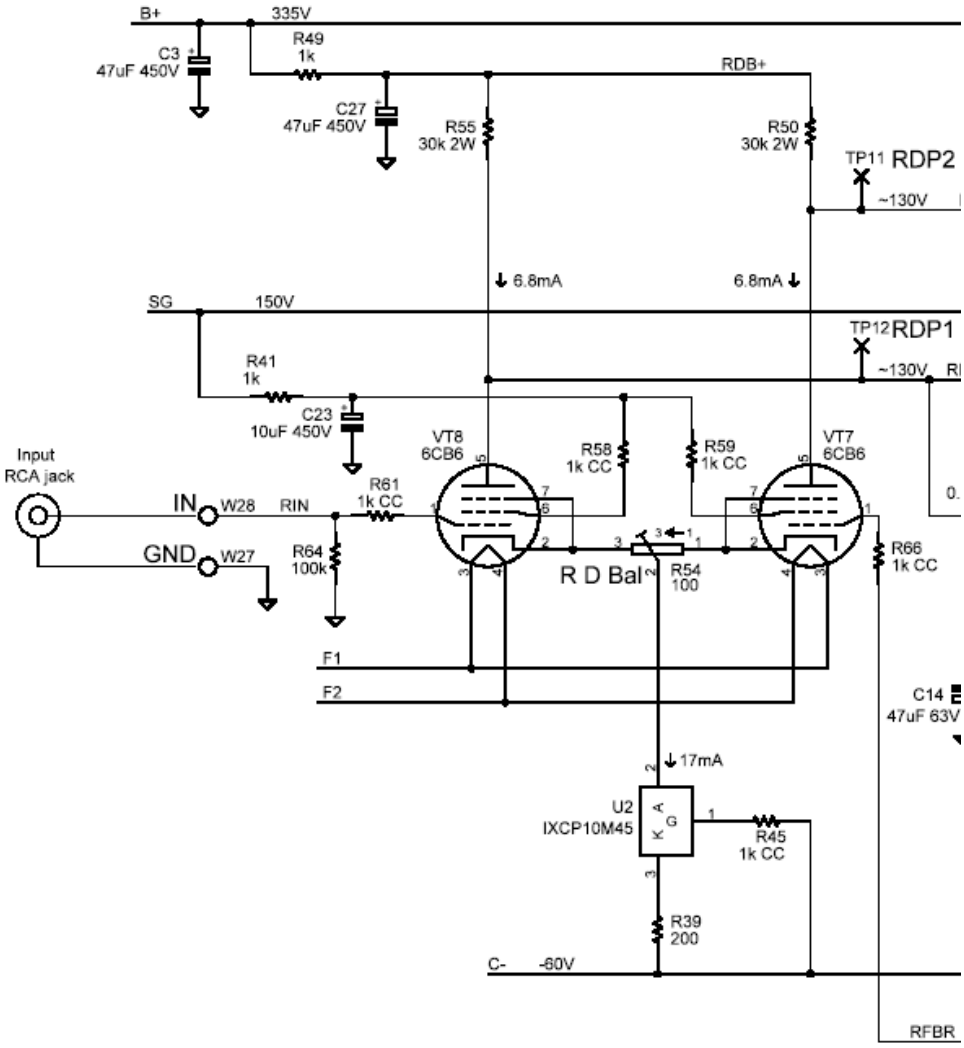
Here is the Full PDF schematic, and the complete bill of materials (BOM) in XLS or PDF format

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The amplifier design

This amp is a 2-stage push-pull pentode design. It puts out just shy of 20 watts.

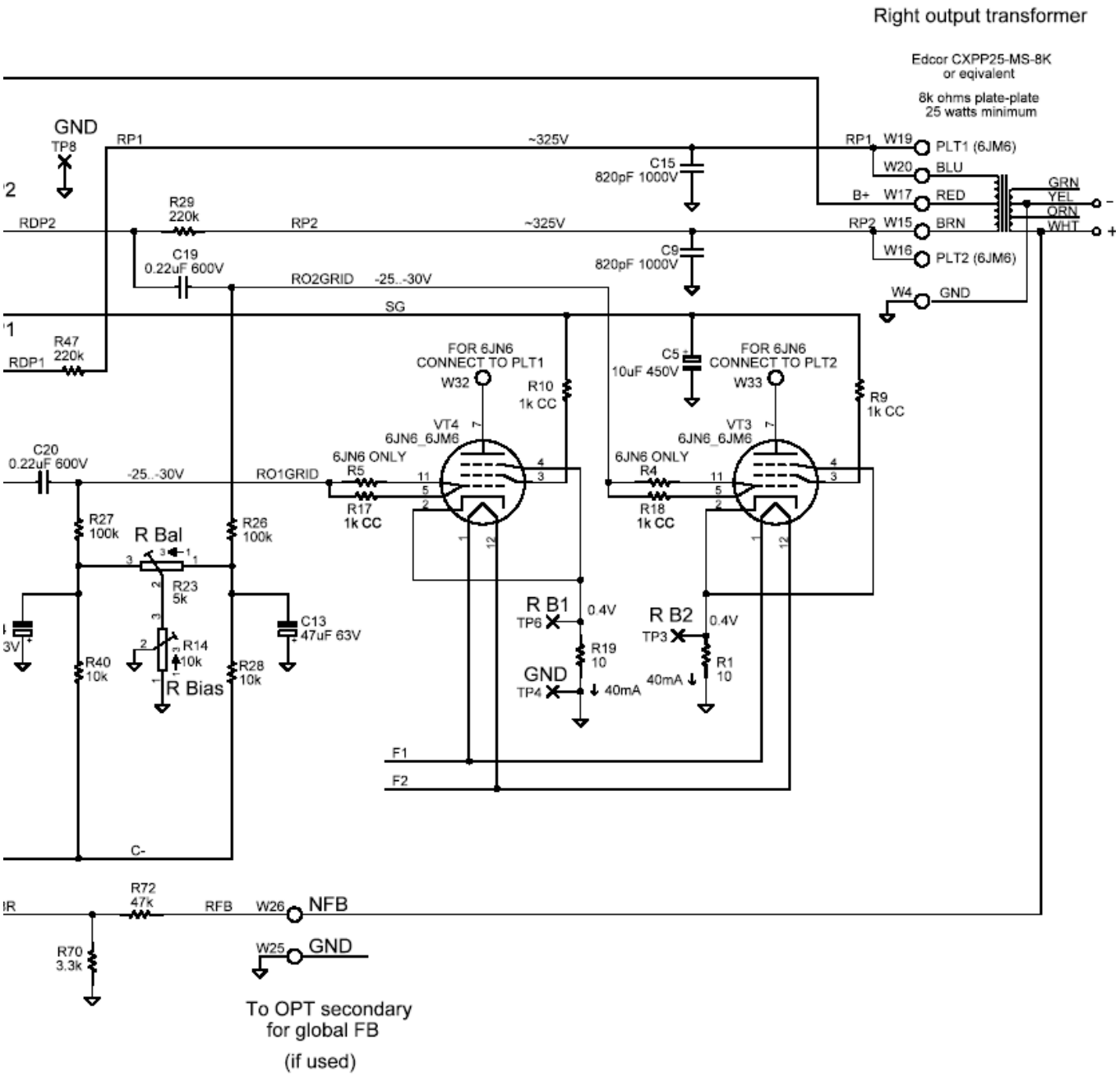
The input /driver stage uses a pair of 6CB6 pentodes in a differential amp configuration, using a silicon CCS in the tail. For the CCS I used a simple Ixys ICP10M45S part. A driver bias balance adjustment is available to minimize the overall distortion. One grid of the diff pair is used as the input, and the other can optionally be used to apply loop feedback from the output. I tested the amp with and without 6dB of NFB connected.



The output stage uses 12-pin compactron TV sweep tubes, either 6JN6 or 6JM6 / 6GV5, which have a 17.5 watt plate dissipation. The 6JN6 is easiest because the plate is connected to a pin on the base; the 6JM6 or 6GV5 requires a plate cap connection to be wired down to the PCB.

The output stage is biased such that it remains in class A1 operation until somewhere over 10 watts, where it enters AB1. Onset of clipping (where the power stage grids start hitting 0V) is at about 18 watts.

Like most sweep tubes, these tubes have relatively low screen grid (G2) voltage ratings, so the screen is supplied with a regulated ~150V. Fixed bias is used on the output tubes, adjustable for both tubes so the plate currents can be balanced.



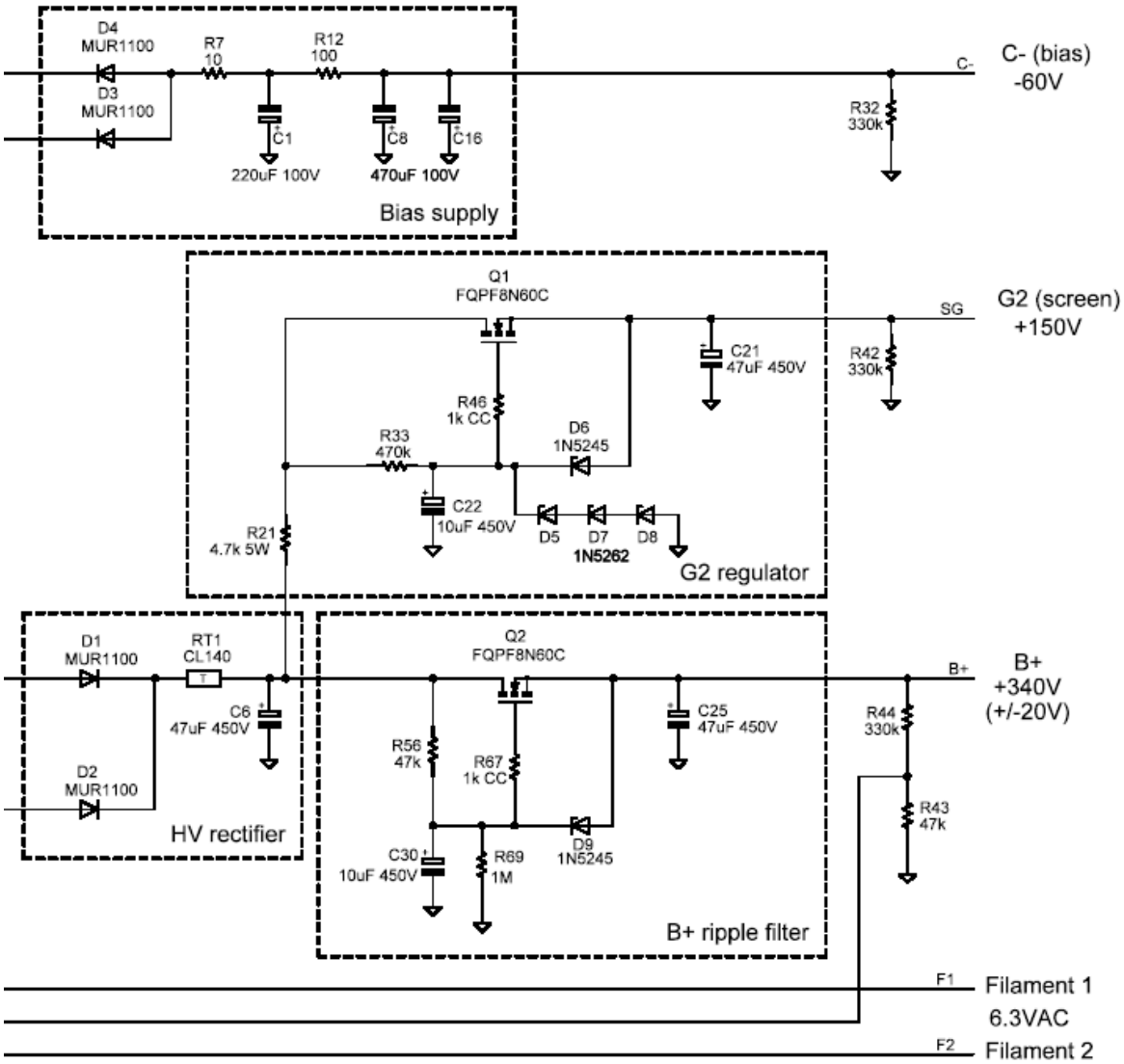
There is local feedback around the output tubes, in the form of plate-to-grid feedback (ala Schade) of about 10%. It's implemented as resistors from the plates of the output tubes to the plates of the driver tubes (the 220k resistors R29 and R47 above). This linearizes the output stage and provides a reasonably low output impedance of about 2.8 ohms (without loop feedback). You see small caps (820pF) from plate to GND to optimize square-wave response in the feedback path.

This circuit employs a considerable amount of distortion cancellation between the driver and output. Though some people will tell you that stage-to-stage distortion cancellation in a push-pull amp does not work, I can assure you it does. (Hint: think of this as two separate, identical single-ended amps that just happen to be joined at the hip). I selected the driver tube type experimentally to optimize the cancellation, winding up with a cheap IF amp pentode that - by itself - is not particularly linear. The most surprising thing to me was how well the cancellation holds over varying load impedances - I suppose the plate-to-grid local feedback helps out there. Anyway, at low power levels (~1 watt) the THD (with no loop feedback) is reduced by almost half compared to what I got using a very linear driver tube.

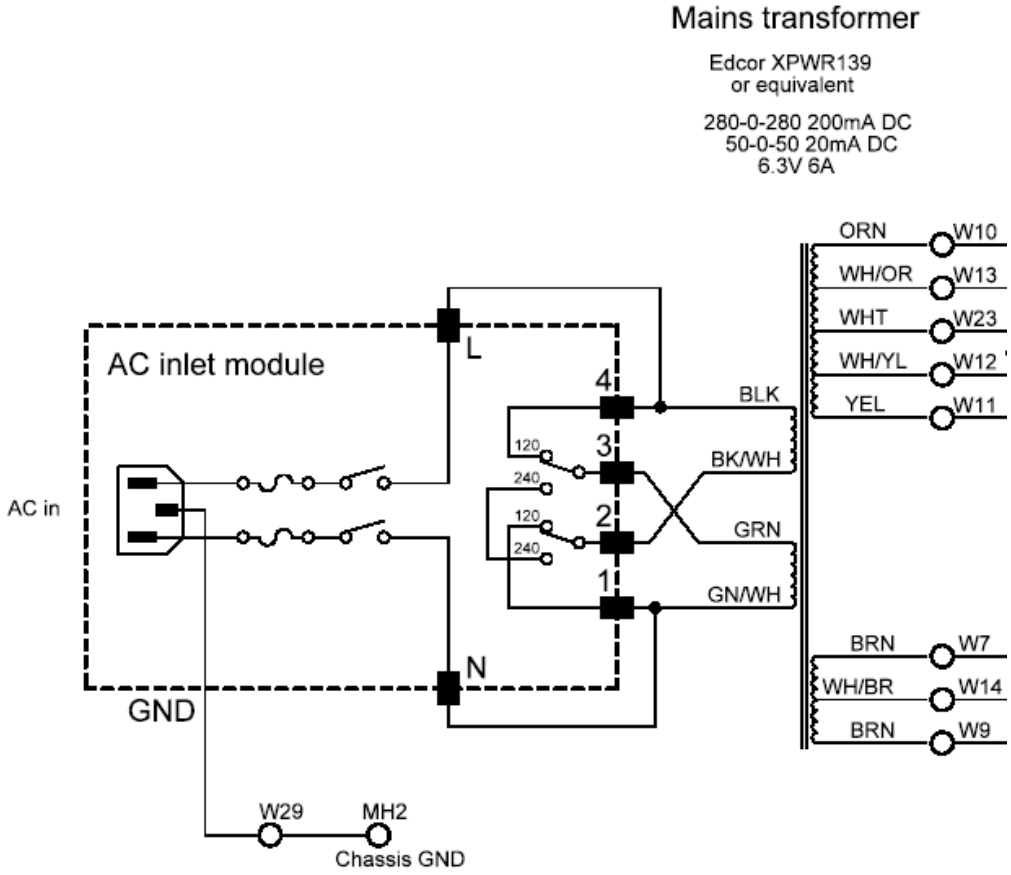
The power supply

The power supply uses silicon rectifiers and a MOSFET ripple filter for the B+ - no expensive and heavy chokes here. The screen voltage of ~150V is generated from the raw HV supply with a simple MOSFET regulator. These circuits are minimalist designs - no fancy triple-cascoded regulators because, frankly, I do not believe they're needed here.

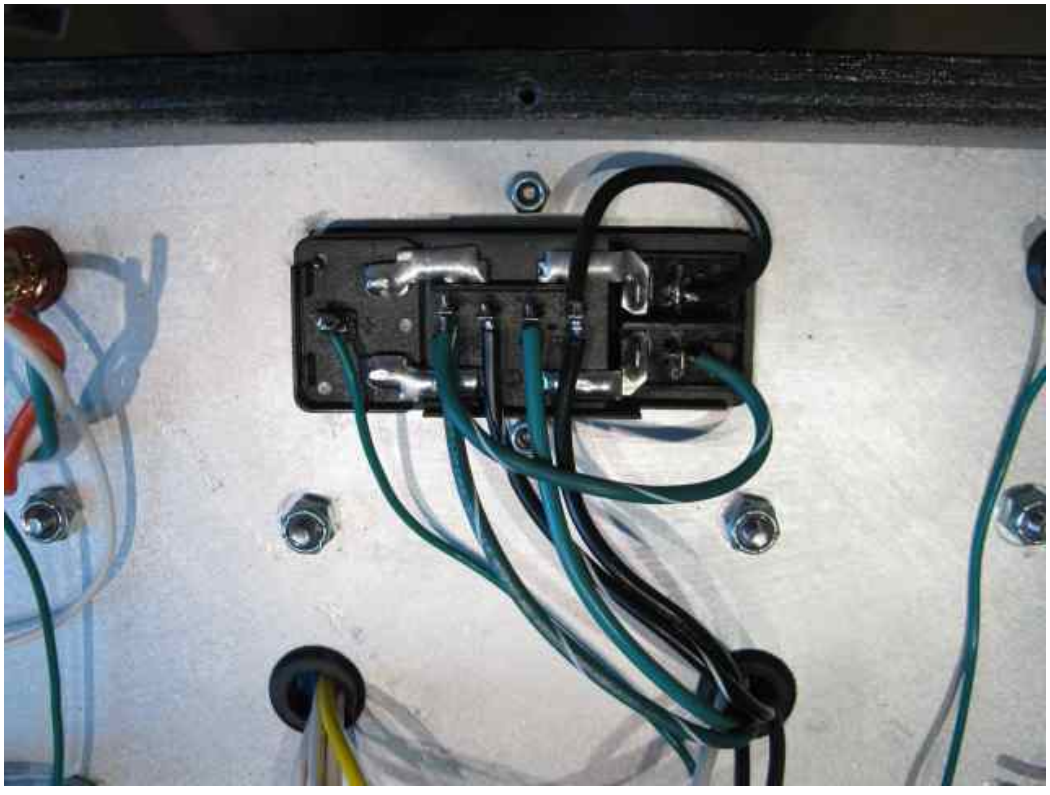
The C- supply of about -60V is generated from taps off the B+ winding, and is filtered by an RCRC filter with no regulation.



The power transformer was specially designed and built for this amp by Edcor. It has a secondary that has two taps to provide both the raw HV of about 360VDC and a negative supply of -60V that's used for output tube bias and a return for the driver CCS. The nice thing about Edcor power supply transformers - in addition to their very reasonable prices - is that once they design a power transformer it becomes a standard product, so other people (like you!) can go buy one - just order an XPWR139.

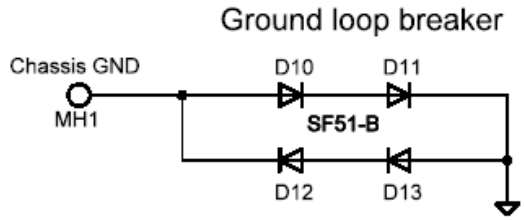


The power transformer has a split input primary so can be set up for 120V or 240V operation. I connected the primary to an inexpensive AC entry module that integrates fuses, the power switch, and a voltage selector. This way you do not have to do a lot of AC power wiring. The wiring for this is a little tricky, though, and if you do it wrong you may get smoke and flames - so here's a close-up photo of it:



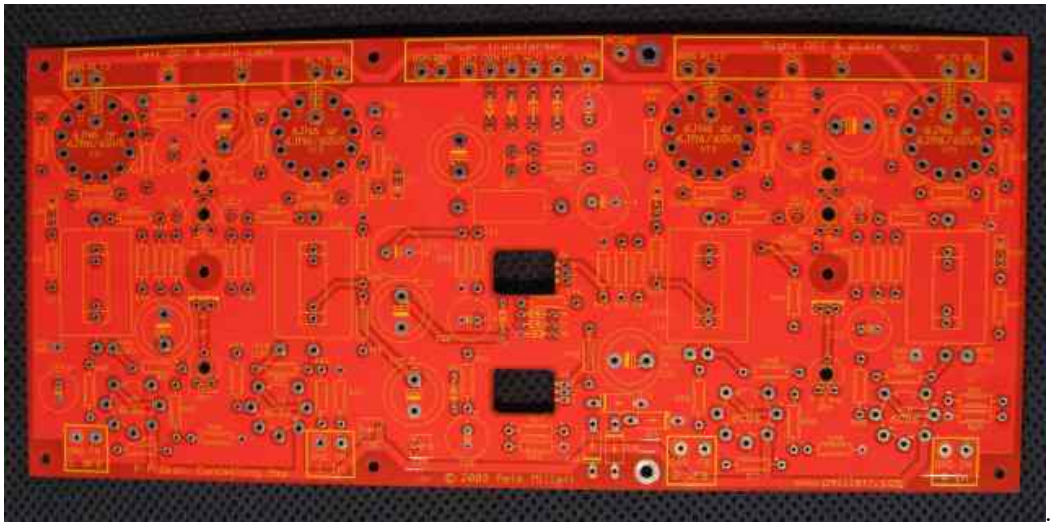
I isolated the AC safety ground, which is connected to the AC plug ground and the chassis, from signal ground using a "ground breaker" circuit. This is an arrangement of series / anti-parallel diodes that presents a high impedance unless there is a voltage of more than two

diode drops (about 1.4V) across them. These diodes are large - they must be sized such that enough current can flow through them to cause the fuses to blow if there were to be a short between signal ground and the AC line.



Construction

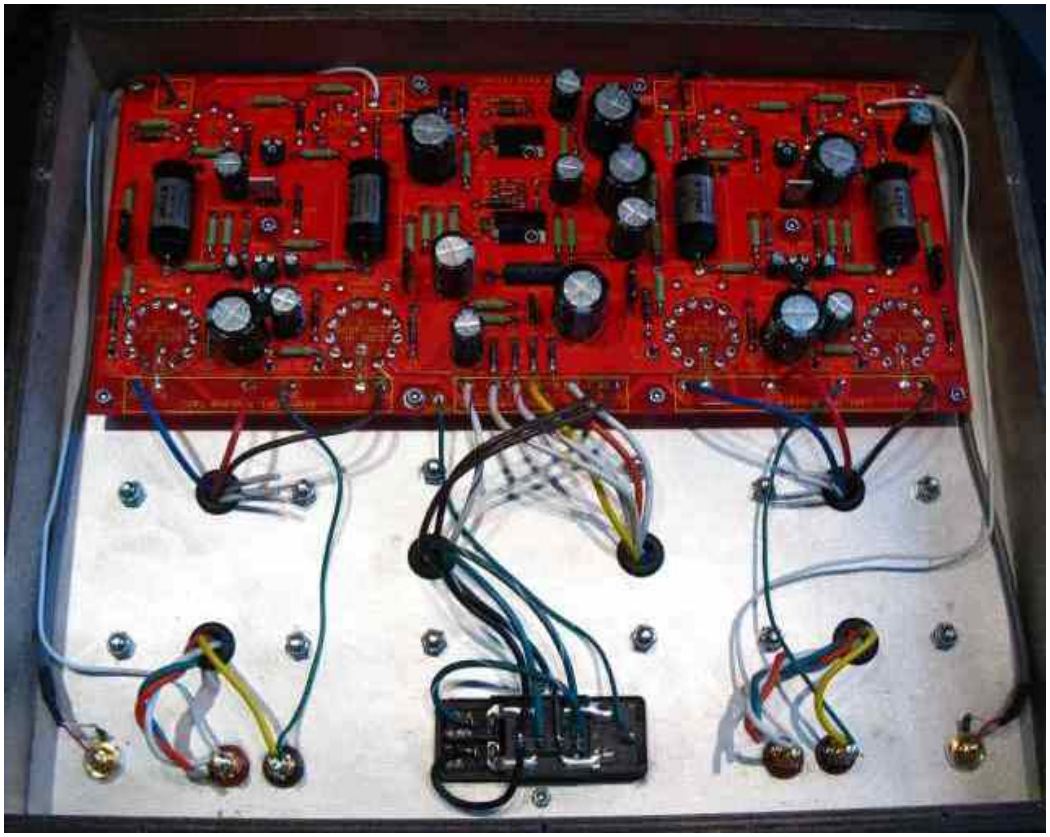
I wanted to make this amp a viable project for a relatively inexperienced hobbyist. To me, that means use of a PCB. A gigantic big bad red PCB!



[Shameless self promotion] I've decided to sell PCBs for this project, instead of just throwing it out there for somebody else to pick up. I figured it would be nice to make this hobby self-sustaining. If you're interested in a PCB, click here to see my listings (seller "pmillett"). *[End shameless self-promotion]*

The PC board holds all the components, including the tube sockets. Tube sockets are mounted on the back of the PCB so that they can stick through holes in the chassis, while all the other parts are mounted inside pointing down. The PCB is 13" long by 5.75" wide.

Note that there are some assembly differences depending on if you are using 6JN6 tubes (no plate caps) or 6JM6/6GV5 tubes (with plate caps). For 6JN6 tubes, install grid stopper resistors R3, R4, R5, and R6; for 6JM6/5GV5, install R16. R17, R18, and R20 instead. These resistor options are also noted on the BOM. Also, for 6JN6, you need to install a jumper wire between the PLTx pad and a pad near the center of the power tube sockets. For 6JM6/6GV5, you connect ,a wire from the PLTx pad to the plate cap. You can see all this in the photo below, which shows the amp wired for 6JN6 (click on the picture to see the high-res version).

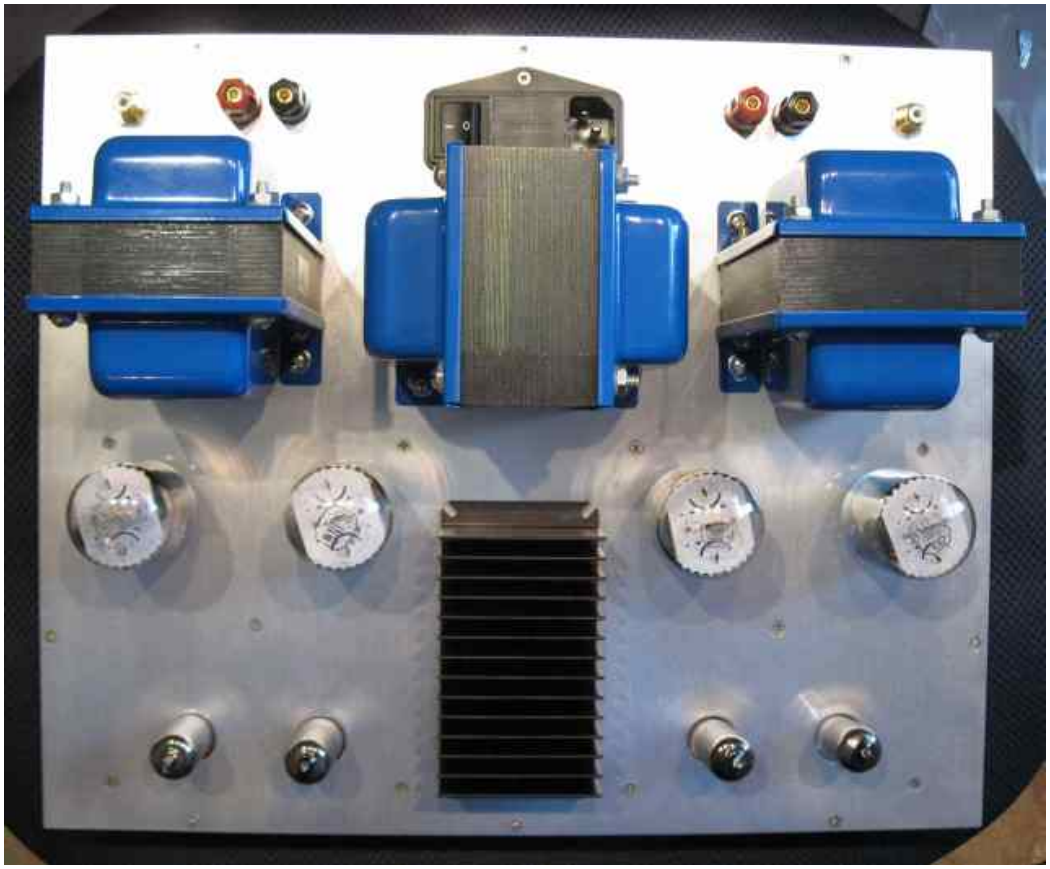


On top of the chassis, the transformers are mounted, as is the AC inlet and input and output jacks. I did it this way so that you can build a simple, inexpensive chassis using flat sheets of aluminum and a simple wood frame. For the panels I ordered cut-to-size 0.08" thick 5053 aluminum sheet from Online Metals. The wooden frame I made from scraps of 1/2" birch plywood I had laying about from a previous guitar amp project. You could also use the small "craft wood" that you can find at places like Lowe's and Home Depot. I glued it together (with simple butt joints) and painted it with a spray can of black Hammerite.

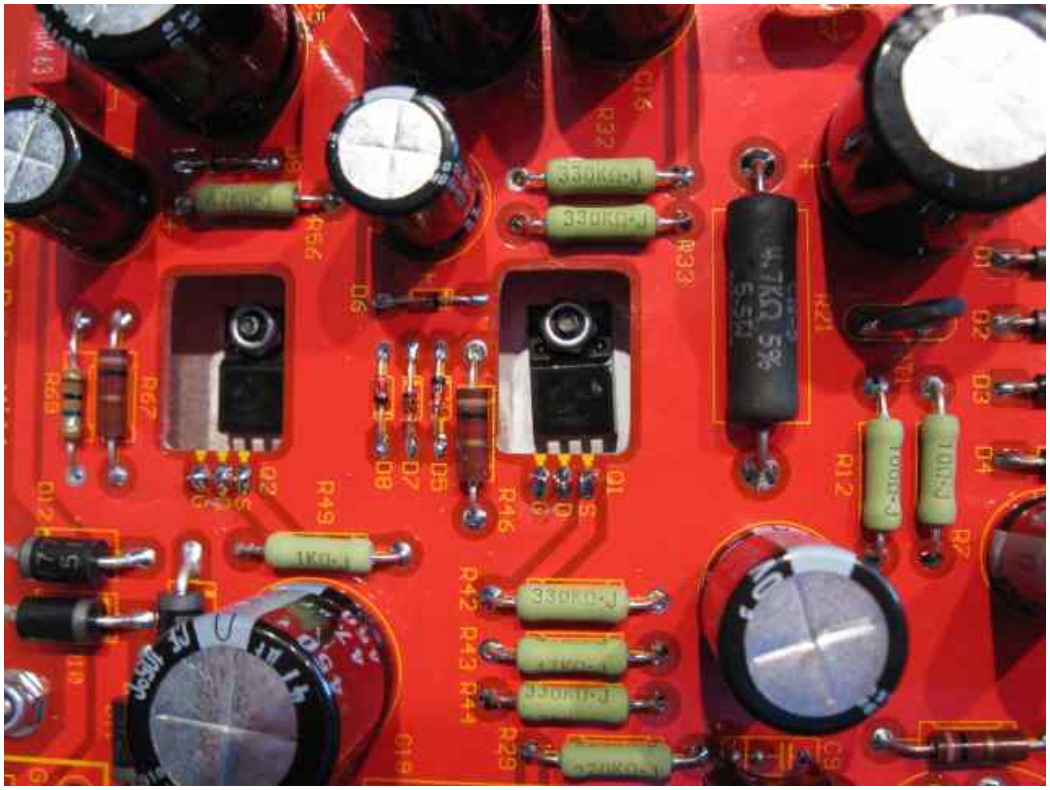
You can download mechanical drawings in a couple different formats. Here is an AutoCAD R12 DXF file of the amplifier mechanics, or a scaled PDF file (scale is 0.75x) showing it. Also, here's a PDF file of just the chassis plate scaled to print on 4 sheets of regular letter paper at 1x scale. You can use this to fabricate the chassis - just tape/glue the sheets to the metal and drill away.

And here is a front panel express FPD file. Beware, I am not 100% sure that it is all correct!

You can, of course, use a conventional aluminum chassis, or another enclosure.



You probably noticed the black heatsink on top of the amp. Originally I planned on just using the chassis plate to heatsink the two power MOSFET transistors in the power supply. It worked OK but the top of the chassis got a little warm. So, I added a heatsink to the top. It mounts using the same holes as the MOSFETs, with a screw going through the heatsink, chassis plate, and MOSFET and a nut on the back. Here's what that looks like from the inside...



To make this work out I had to extend the MOSFET leads a bit. I soldered short pieces of wire to the leads and put some heat shrink tubing around them just in case...

Use silicone thermal compound between the MOSFET and the chassis plate, and also between the chassis plate and the heatsink. Any heatsink will do, or if you don't mind a hot amp you probably don't need a heatsink at all. Even a couple of stick-on BGA heatsinks would work.

Adjustments

There are three adjustment pots for each channel that you need to set up.

Start with both "bias" pots fully counterclockwise (as viewed from inside the chassis) - that sets minimum output stage plate current. The other two pots can be left alone, or centered (they normally come from the factory that way).

The easiest way to set the bias is with two meters (any DMM will work), but you can use one and alternate between test points. You'll find three test points near the power tubes for each channel, labeled LB1, LB2, and GND (left channel) and RB1, RB2, and GND (right channel). The voltage between the xBx test point and ground is an indication of the plate (actually cathode) current through each output tube. The current is sensed across a 10 ohm resistor, so 1mA of current will read 10mV on a DMM.

The target cathode current is 40mA for all four tubes. That means 400mV, or 0.4V, on all four of the test points.

After you power the amp up (the first time it's a great idea to do this with a variac, so you can stop if you smell smoke) and verify that the plate voltage is OK (around 325V) and the screen voltage is OK (around 145V), move the bias control up (clockwise) so you are measuring around 400mV on the test points. The balance pots will change the ratio of current between the two tubes, so moving it can make the voltage equal on the xB1 and xB2 test points.

Don't worry about accuracy yet. Let things warm up for a good 10-15 minutes.

Once the amp is warmed up, go back and twiddle the bias and balance pots so you have 400mV on all four test points. You will have to go back and forth as there is some interaction between channels. You want the currents on a given channel to match closely (within a few mV is best), as this balance has a big affect on low-frequency distortion.

Once the outputs are set, you can adjust the driver balance. There are two ways to do this:

If you have access to a distortion measurement or FFT (like a soundcard), set the driver balance for the lowest distortion at about 1 watt output.

If you don't have a way to measure distortion, you can set the pot so that the voltage on the xDP1 and xDP2 test points for a given channel are equal (it doesn't mater if the two channels are different). Or, if you have superhero hearing, set it by ear.

If you cannot achieve balance in either the output or driver tubes, try swapping tubes around, or try different tubes. These tubes are cheap, so you can afford to buy extras...

It is wise to repeat the bias adjustments periodically as the tubes age. You'll also want to repeat it if you change tubes.

Measurements

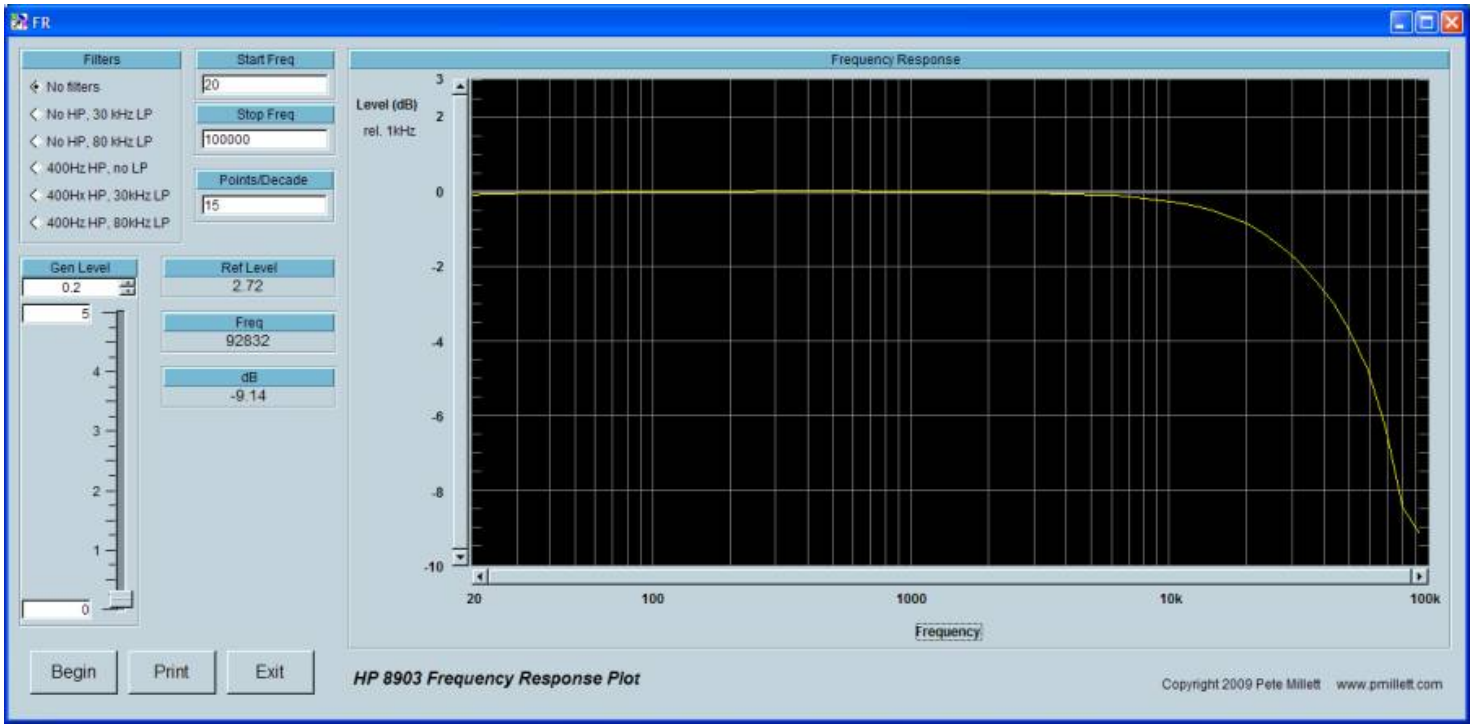
I set up and made measurements of the amp with and without the 6dB of global feedback. Here is a summary:

	Without loop feedback		*With 6dB loop feedback*	
1 watt out (2.82V RMS into 8 ohms)	0.17% THD	0.21V RMS in	0.09% THD	0.40V RMS in
5 watts out (6.32V RMS into 8 ohms)	0.71% THD		0.40% THD	
10 watts out (8.9V RMS into 8 ohms)	2.26% THD		1.27% THD	
At clipping (5% THD)	17.8W (12V RMS)	0.98V RMS in	17.8W (12V RMS)	1.93V RMS in
Zout	2.81 ohms		2.31 ohms	

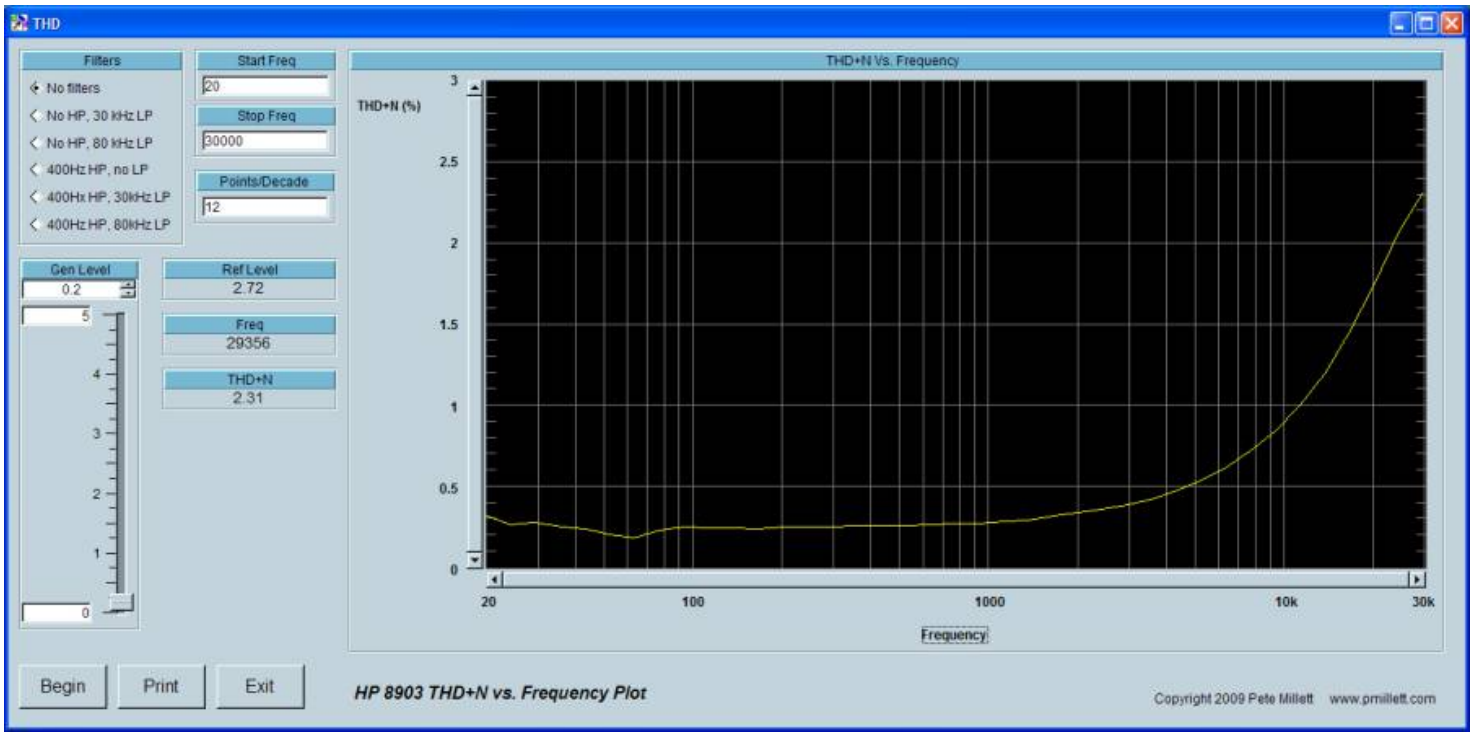
Note that to a large extent, the frequency response and THD vs. frequency performance are dictated by the output transformers. I used Edcor transformers here (CXPP25-MS-8K), which are affordable and measure pretty well. I also tested using some expensive "imported" iron; the THD at high frequencies was considerably better (nearly flat to above 20kHz) and the HF response extended slightly.

And a bunch of plots... first set *without* feedback:

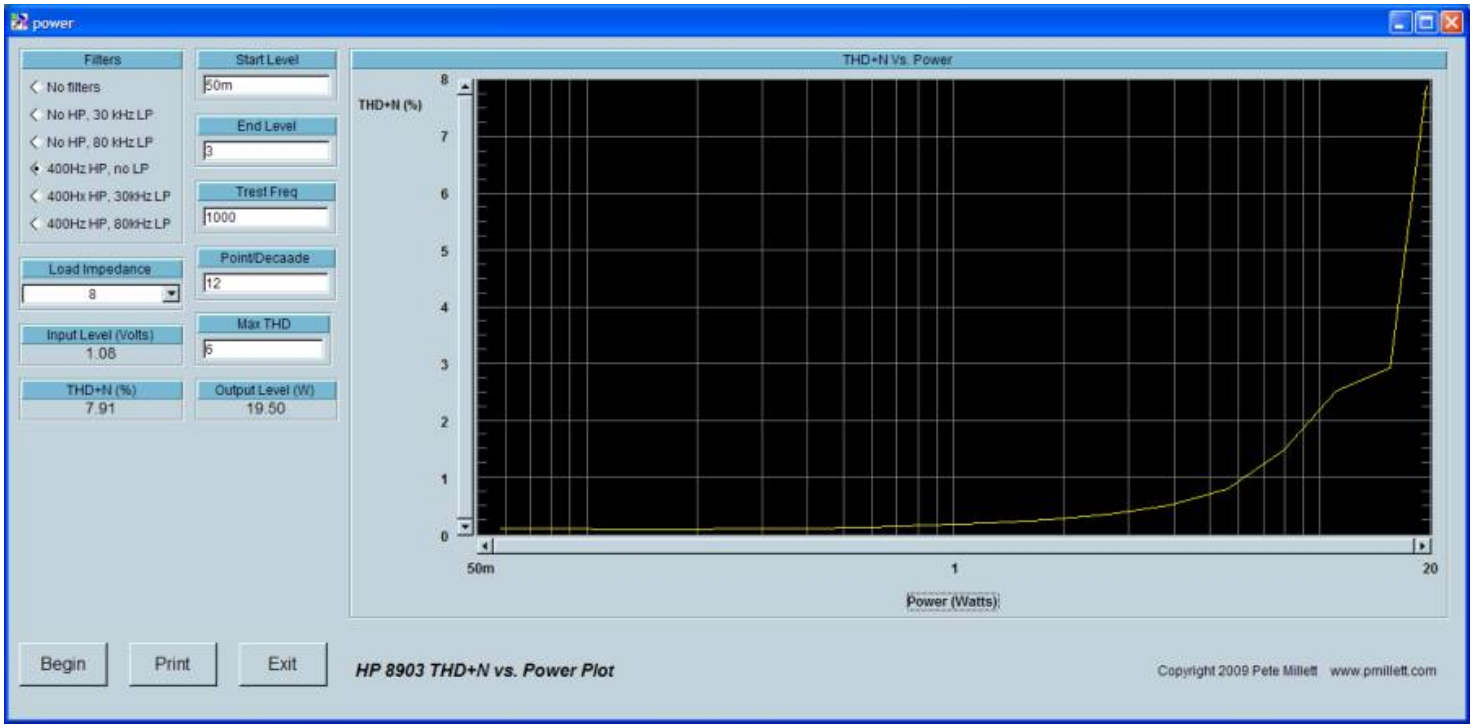
Frequency response @ 1W into 8 ohms :



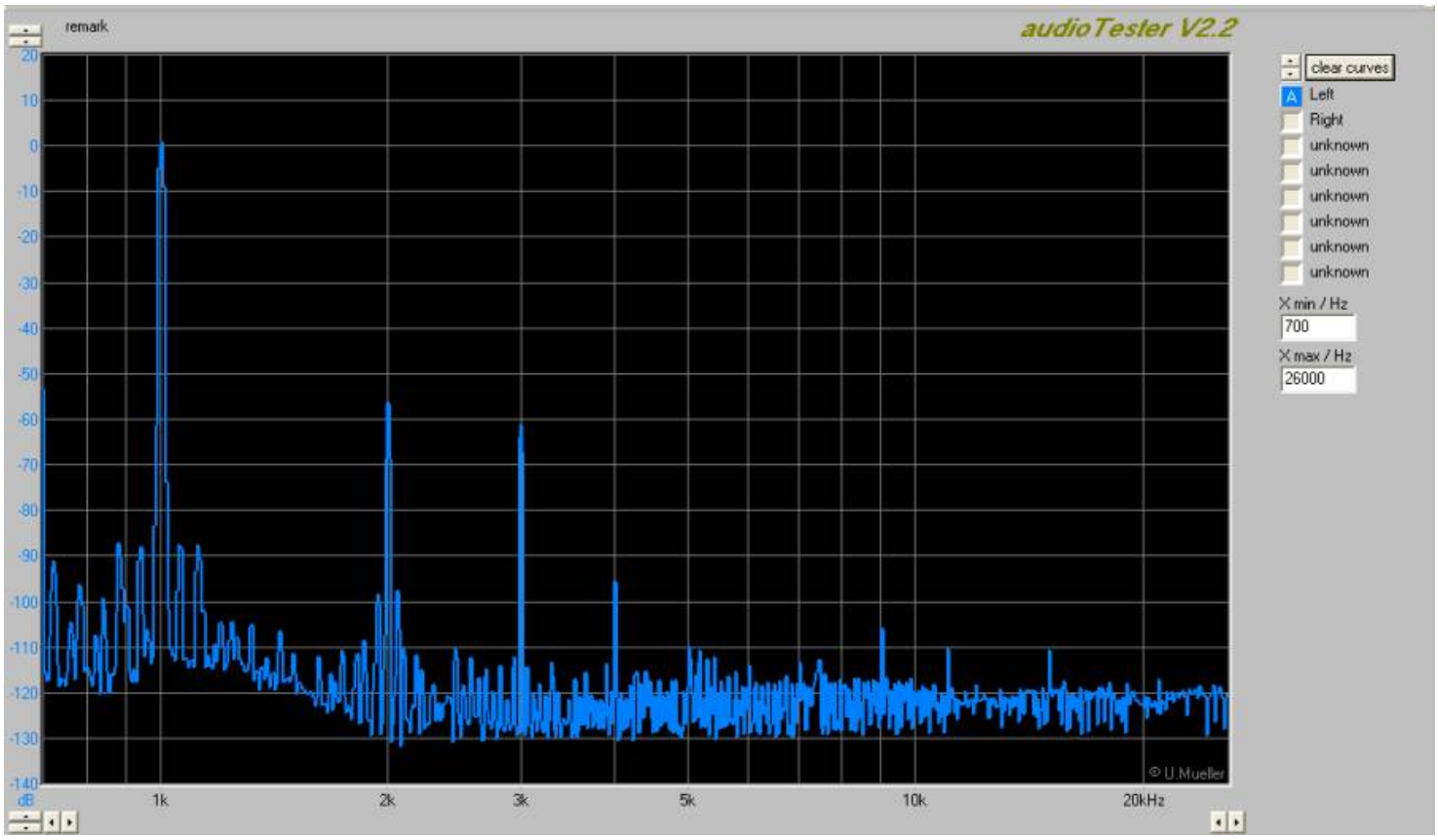
THD+N vs. frequency @ 1W into 8 ohms (note no filters used so some 60Hz noise shows up)



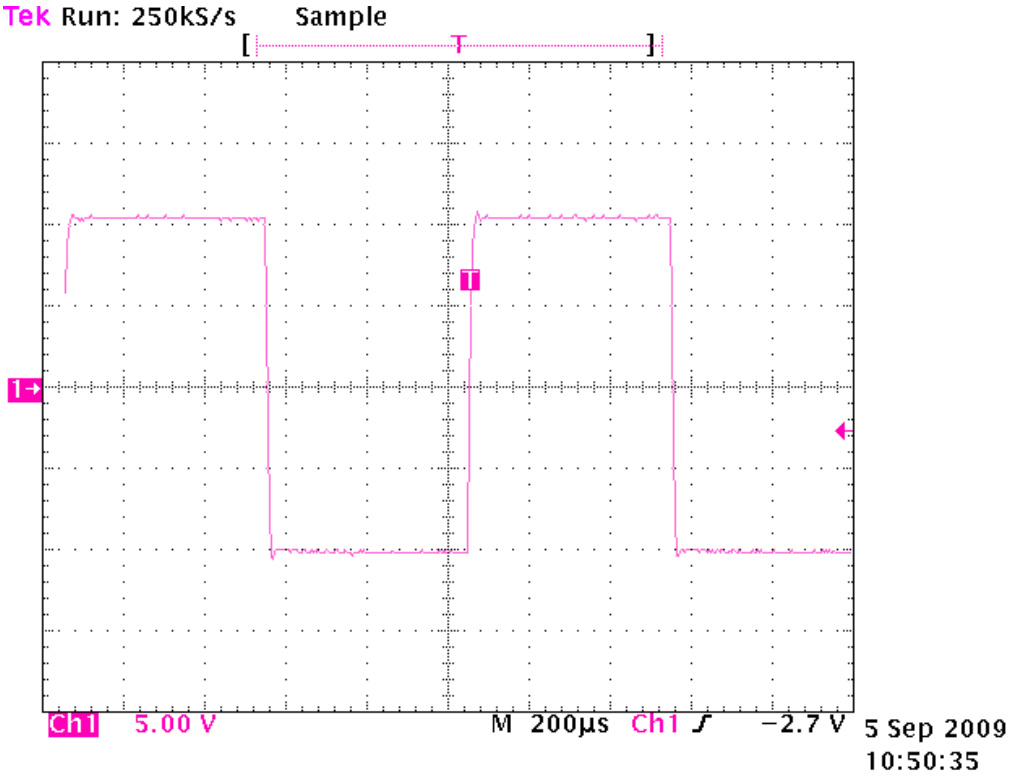
THD+N vs. output power (into 8 ohms):



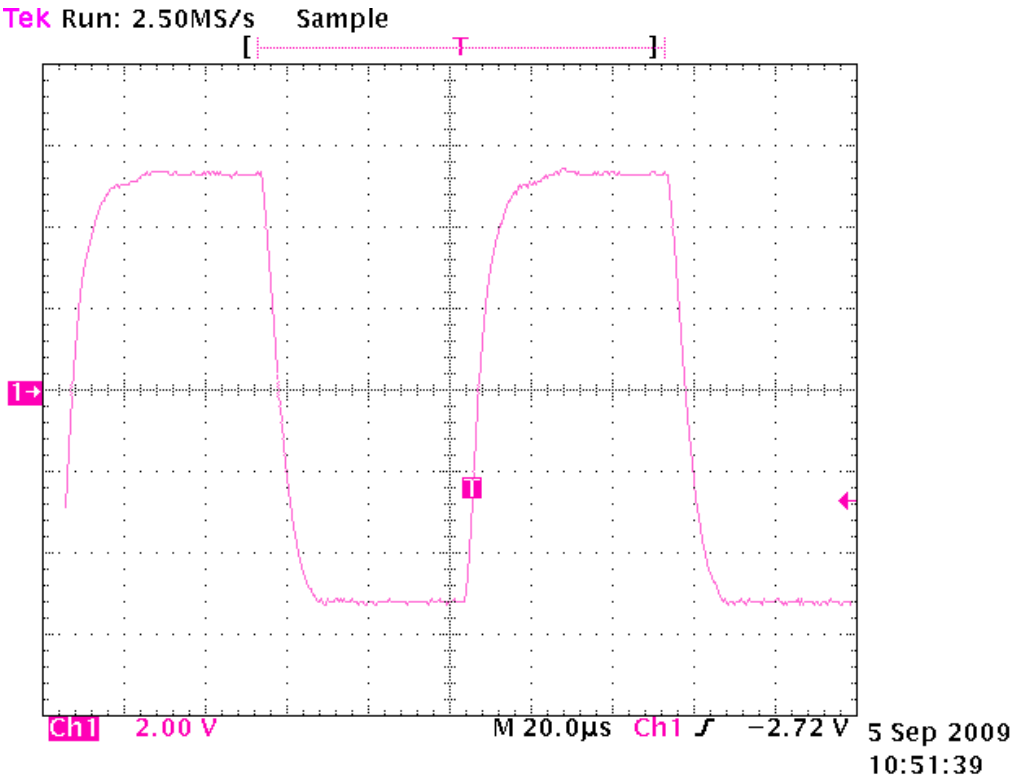
FFT @ 1kHz, 1W into 8 ohms:



Square wave response - 20V P-P @ 1kHz into 8 ohms...

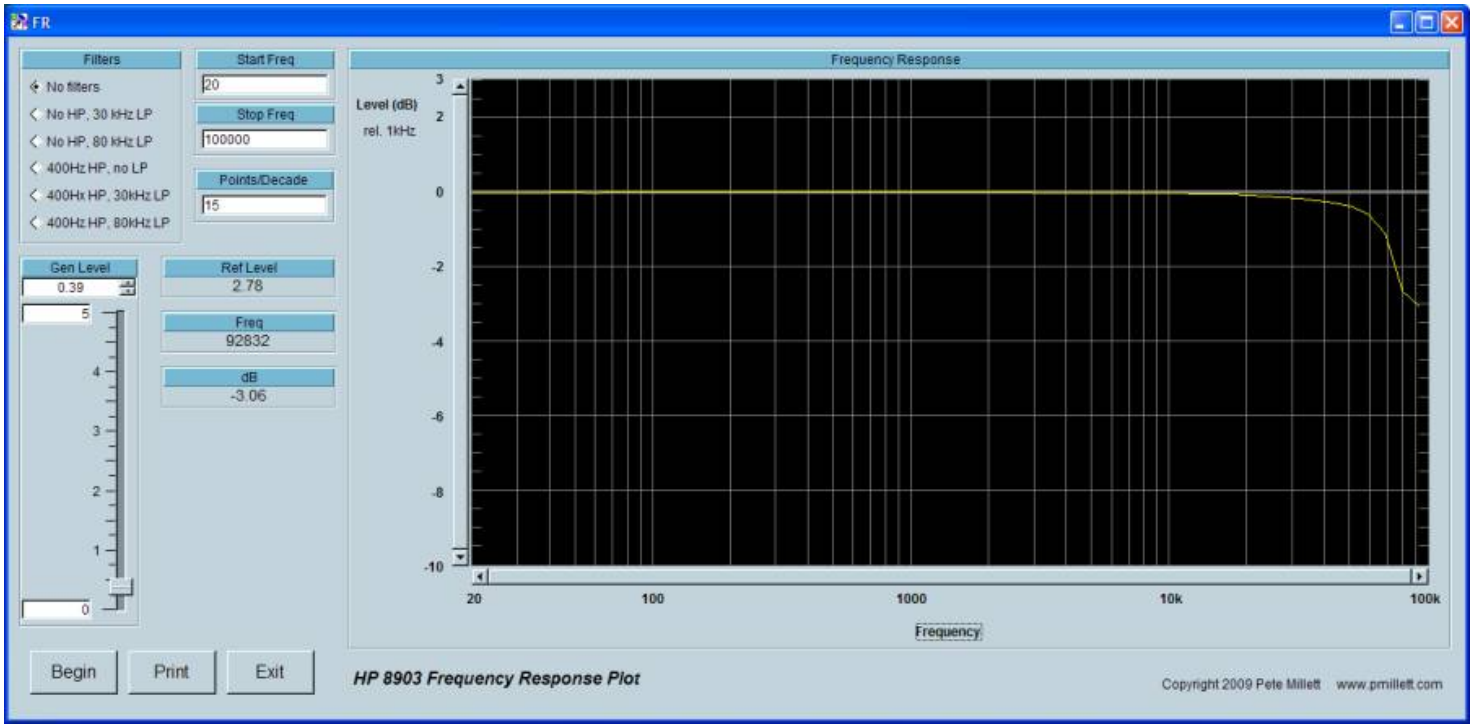


...and ~10V P-P at 10kHz into 8 ohms:

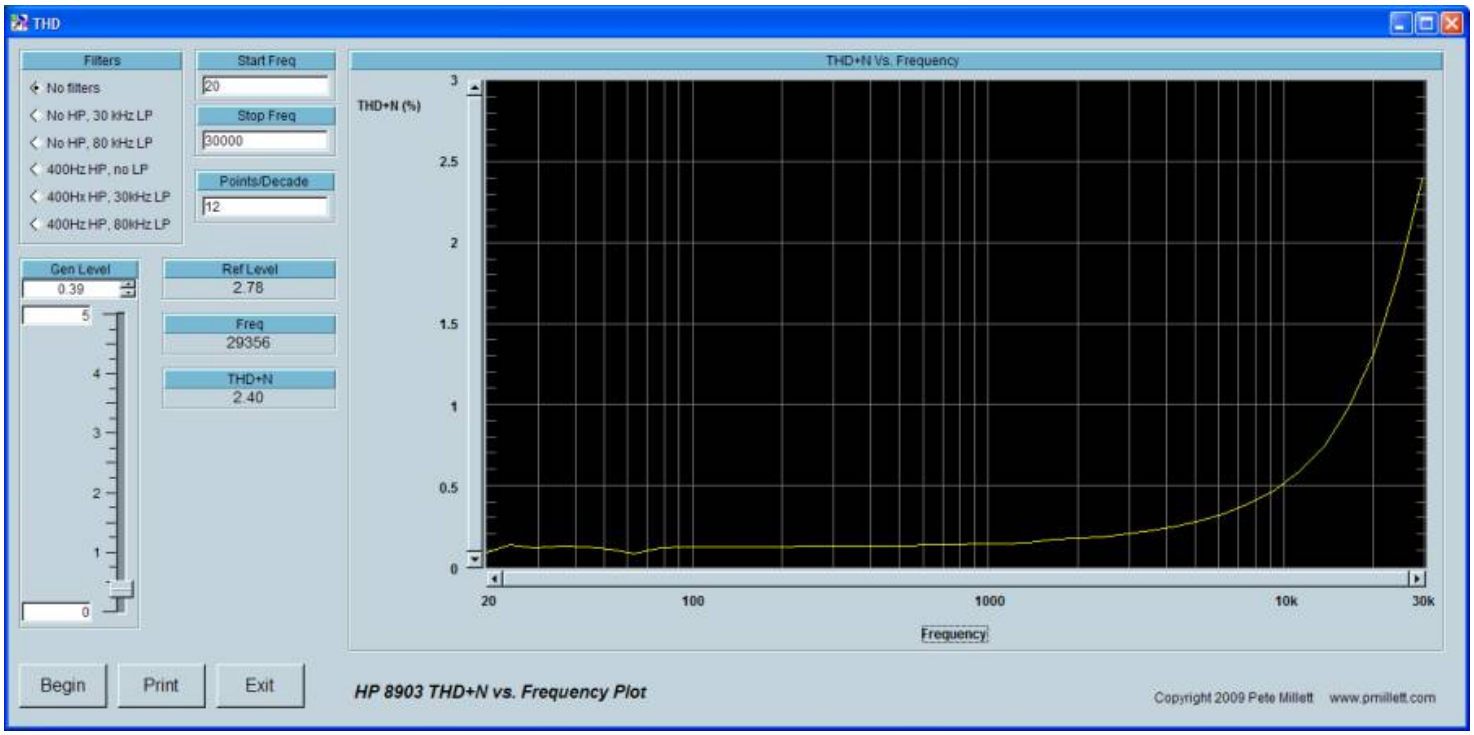


Now plots *with 6dB of loop feedback*... about what you would expect: lower THD and noise, flatter FR, but a few higher harmonics and a little funkiness on HF square waves...

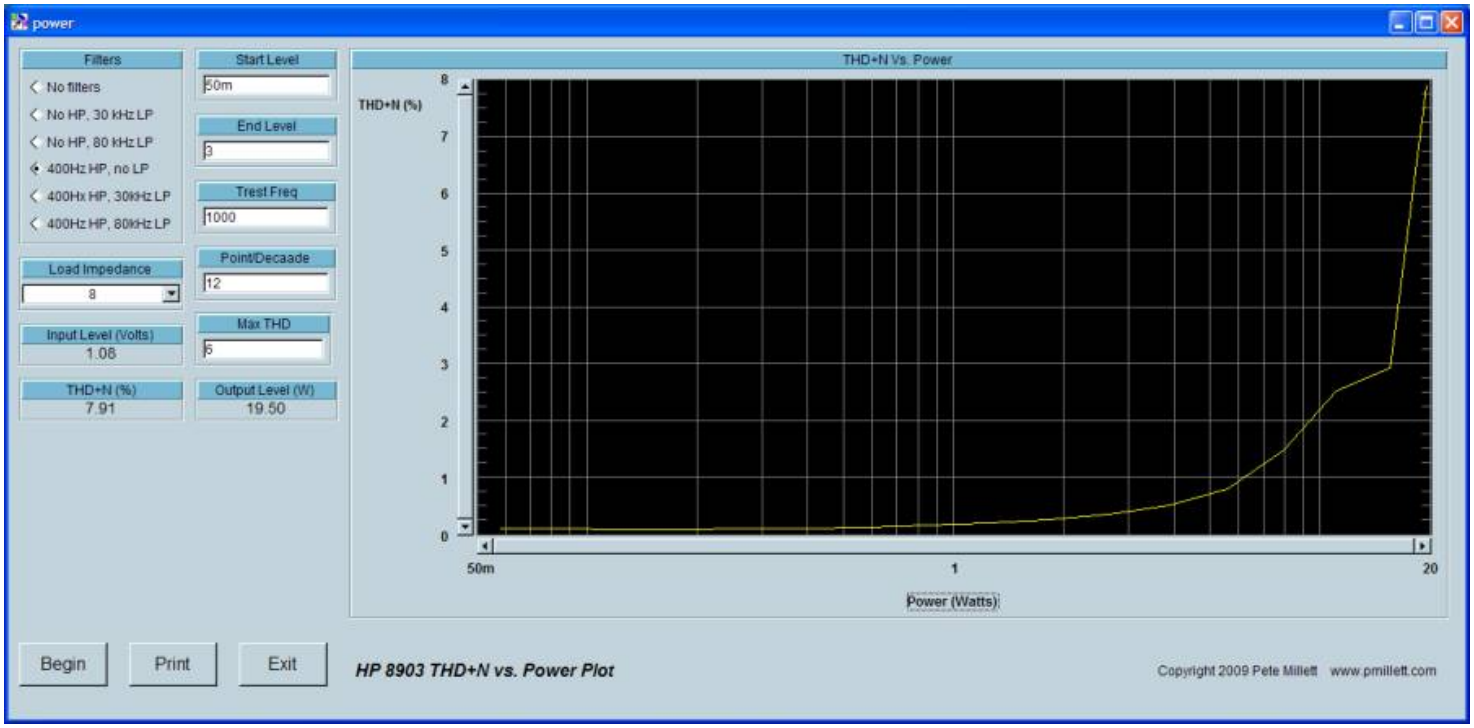
Frequency response @ 1W into 8 ohms :



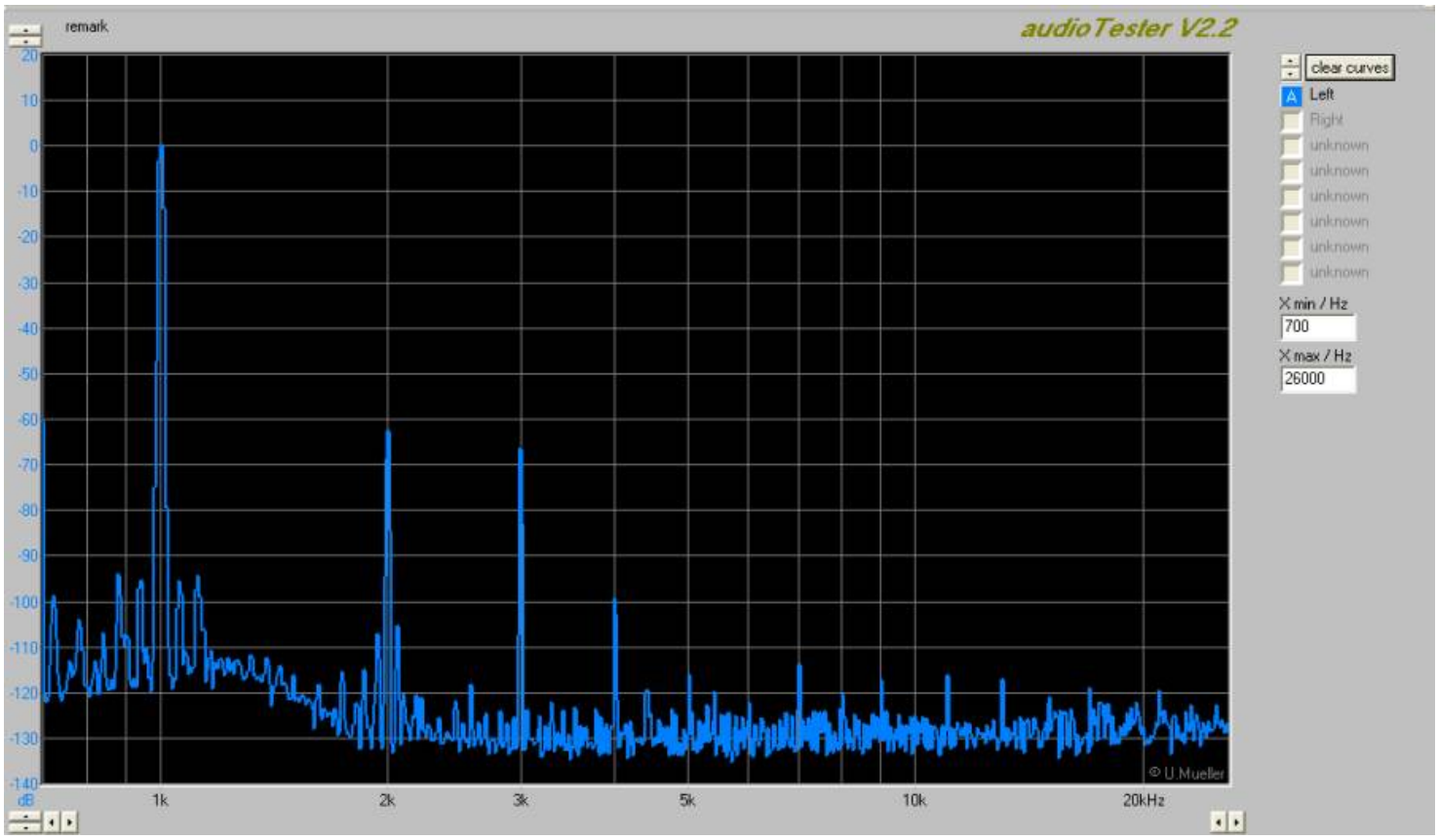
THD+N vs. frequency @ 1W into 8 ohms (note no filters used so some 60Hz noise shows up)



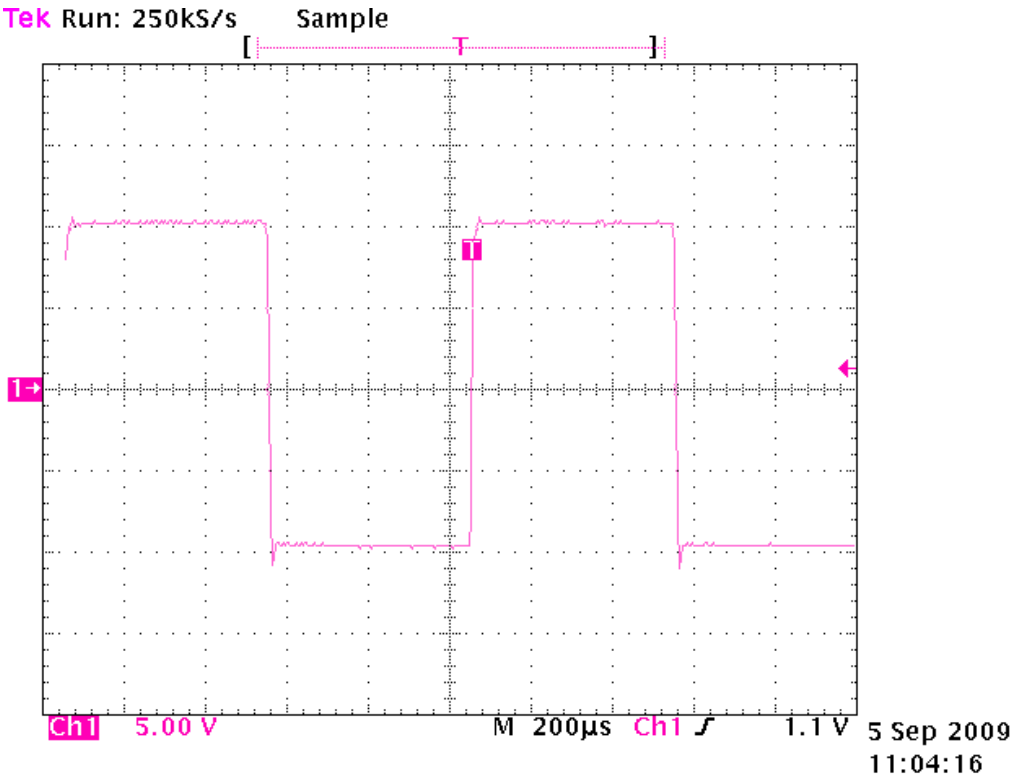
THD+N vs. output power (into 8 ohms):



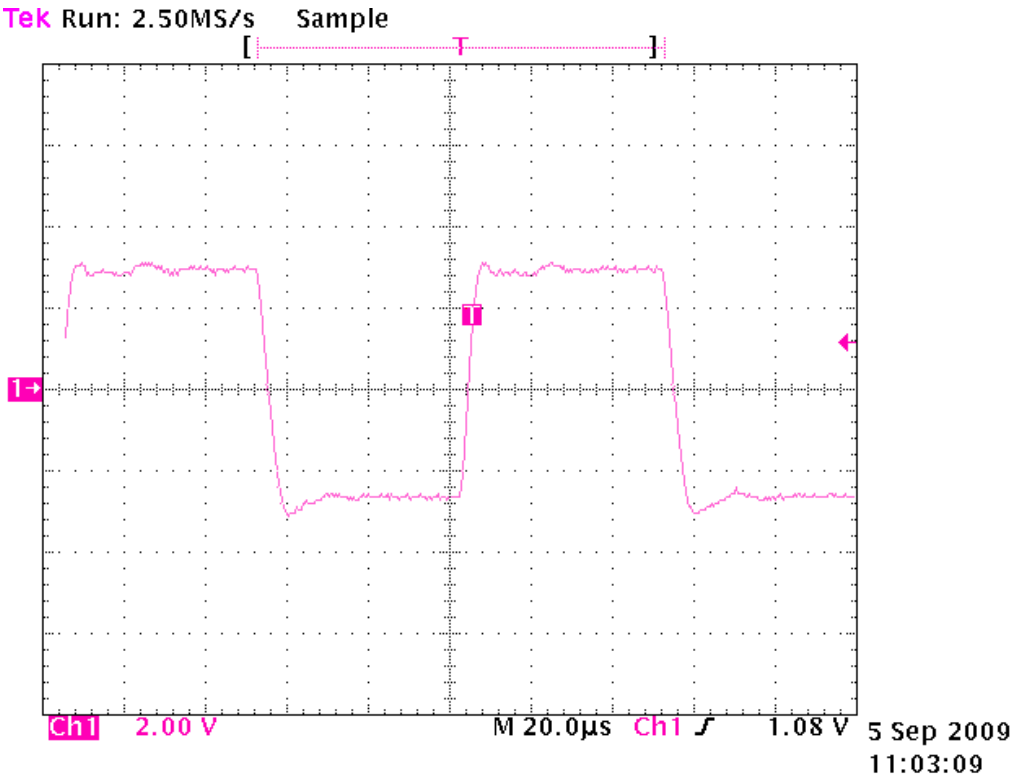
FFT @ 1kHz, 1W into 8 ohms:



Square wave response - 20V P-P @ 1kHz into 8 ohms...



...and ~6V P-P at 10kHz into 8 ohms (sorry, different level than the other plot):



How does it sound?

I *hate* that question. After all, I *am* an engineer...

Well, I like it. I like it a lot.

It possesses none of the syrupy smoothness that the 300B amp had. It is tight sounding - wonderful bass response (as the measurements would suggest). I think I prefer it with the loop feedback, though honestly there is not much difference to my ears with or without the feedback.

Those accustomed to SET amps might find the sound a little edgy, especially if you're using horn speakers. But it's moderate damping factor seems to take some of the edge off, and it plays well with all of the speakers I've tried, including Jordan MLTQWPs, Fostex FE167s, and Klipsch Heresys. With 18W the Heresys will drive you from the room...

Above all, for a tube amp, this amp is *accurate*. The measurements confirm it.

How to Create a Simple AM Radio

Three Parts: Pre-Assembling Necessary Components Wiring the Electrical Components Finishing the Radio

Radio stations broadcast on medium-wave bands and send signals into the air all around us. Only a few simple parts are needed to pick up AM radio waves: some electronic components, wire, a paper tube, and a speaker. Assembly is simple, and doesn't require any soldering. This simple radio will be able to pick up signals transmitted within 50 kilometers (31 mi).

Part 1 Pre-Assembling Necessary Components

1 **Gather your supplies.** You likely already have many of the parts you'll need for this project, excluding some of the electrical components. These can be bought at most hardware stores, home centers, and electronics stores. You'll need:

- 1 megaohm resistor (x1)
- 10nF capacitor (x1)
- 15-20 in (25.4-50.8 cm) of red and black insulated wire
- 2,000 or 2,200pF variable tuning capacitor
- 22uF electrolytic capacitor (x1)
- 33pF capacitor (x1)
- 50-100 feet insulated wire (any color; for the antenna)
- 9-volt battery (x1)
- Breadboard
- Electrical tape
- Operational amplifier (also called an op-amp; x1)
- Small, non-conductive cylinder (glass bottle, cardboard/plastic tube, etc.)
- Speaker
- Wire strippers (or a similar item, like sharp scissors or a knife)

2 **Make an antenna.** The antenna is one of the simplest parts of a homemade radio: all you need is a long piece of wire. Ideally, the wire should be 50 feet (15.2 m) (15.2 m) long, but if you don't have that much, you can use as little as 15 or 20 feet (4.6 or 6.1 m) (4.6 to 6.1 m).

- When choosing wire for your antenna, prioritize small diameter insulated wire (like ones in the 20- or 22-gauge), as these work best.
- Boost the reception of your antenna by looping its wire into a coiled circle. You can keep the coil from unraveling with zip ties or electrical tape.[1]

3 **Cut and strip jumper wires.** Jumper wires will connect components installed on the breadboard later. Cut one piece of black wire and one piece of red wire so that each is about 5 in (12.7 cm) long.[2]

- Use wire strippers (or a sharp knife) to remove about 1 in (2.5 cm) of insulation from both ends of each piece of wire.
- Jumper wires can always be cut down to size if they turn out to be too long, so you may want to cut these a little on the long side at first.

4 **Make a coil to serve as an inductor.** When you wrap wire around a cylinder with no space in the windings of the wire, it allows the wire to pick up radio waves as electromagnetic energy. This process sounds complicated, but making one is simple. Just wrap wire into a tight coil around a cylinder.[3]

- Start winding your inductor at one end of the cylinder. Leave about 5 in (12.7 cm) of slack where you fasten the wire with electrical tape to the lip of the cylinder. Wrap leaving no gaps in the windings.
- Aim for cylinders 2 to 3 in (5 to 7.6 cm) in diameter. Avoid metal cylinders, because metal will throw off your signal.
- Cardboard cylinders may lose their shape while being wrapped with wire. To prevent this, you may want to glue some supports inside.

5 **Wrap the cylinder completely to finish the inductor.** The more windings your inductor has, the better it'll work. Continue wrapping until the whole cylinder is completely coiled with wire. Fasten the end with electrical tape, then measure another 5 in (12.7 cm) of slack and cut the wire off at this point.

- The windings of your inductor can also be held in place with a liberal application of hot glue or a similar adhesive.[4]

Part 2 Wiring the Electrical Components

1 **Position the breadboard.** Lay your breadboard on the table in front of you lengthwise, so its long edge faces you. Which side faces up won't influence how the breadboard works. Circuit components (like capacitors and resistors) are connected by being inserted into adjacent column holes on the breadboard.[5]

- There is one exception to the connections on a typical breadboard: the long, connected rows at the top and bottoms of it connect left-to right, not up-and-down like the rest of it.

2 **Place your op-amp on the breadboard.** Most breadboards have a long trough running across the middle, separating the board into two equal halves. Place your op-amp centrally on the board so that four pins are on one side of the trough and four are on the other.

- This will allow an uncluttered layout, with the input (the antenna) on one side of the breadboard and the output (the speaker and tuning capacitor) on the opposite side.[6]
- Amplifiers have front and back. You'll find a small, circular divot at the front. The amplifier should always be oriented with the direction of the current.
- The pins of amplifiers are numbered: starting from in the top row moving right to left: 8, 7, 6, 5. From the leg opposite 5 moving right: 4, 3, 2, 1.[7]

3 **Put your 1.0M Ohm resistor over the op-amp.** Current flows both ways over a resistor, so you don't have to worry about its orientation on the board.[8] Place one lead into the hole directly above the op-amp's 7 pin. The opposite lead should be connected to pin 2 of the op-amp.

4 **Place the 10nF capacitor.** Insert the short lead of the 10nF capacitor into the hole directly below the connecting lead of your 1.0M Ohm resistor in the bottom row of op-amp pins. Next, place the long lead of the 10nF capacitor in a hole four columns to the left.[9]

5 **Hook up the 22uF electrolytic capacitor.** Stick the long lead of the 22uF capacitor in the hole directly above the lead connecting your 1.0M resistor to the top row of op-amp pins. The short lead can be put into a hole four rows to the right of the long lead.[10]

- Electrolytic capacitors only accept voltage going in one direction. Electricity must enter in through the shorter lead. Applying voltage incorrectly can cause the capacitor to fail in a puff of smoke.[11]

6 **Add the jumper wires to the circuit.** Use the red jumper wire to connect the hole directly above the 8 pin of the op-amp and the nearest free hole of the long, connected rows at the top. The black jumper wire connects pin 1 of the op-amp to the nearest free hole of the bottom, long, connected rows.

7 **Place your 22pF capacitor.** In the hole above the lead for your 10nF capacitor that isn't yet connected anything, insert one lead for your 22pF capacitor. The other lead of the 22pF capacitor can go in an empty hole four rows to the left.[12]

- This capacitor, like the first one you placed, isn't polarized, so current can pass through it in both directions. It won't matter which lead goes in which spot.

Part 3 Finishing the Radio

1 **Attach the antenna.** The antenna, yet unused until this point, is now ready to attach. Insert one end of the antenna into the hole directly above the empty lead of the 22pF capacitor. This is the same lead you just placed out of the way four rows away to the left.[13]

- You can improve reception by spooling the wire of your antenna across the room as far as possible, or by winding it into a coil as described in the step on making the antenna.

2 **Connect your variable capacitor.** Insert one lead of the variable capacitor into the hole above the rightmost lead of the 22pF capacitor. The other lead connects with the black jumper wire in the long, connected row at the bottom.

3 **Attach the inductor coil.** Use the 5 in (12.7 cm) of slack on either side of the coil to fasten it with the variable capacitor and black jumper wire in the long, connected bottom row. The remaining lead attaches at the 10nF capacitor and the electrolytic capacitor's connection.[14]

4 **Plug in the speaker.** Place your speaker on the table to the right of the variable capacitor. The red lead goes into the topmost row of the board to connect with the red jumper wire. The black lead goes into the hole directly above the short lead of your 22uF electrolytic capacitor.

- In many situations, you'll need to untwist the wires for the black and red leads attached to your speaker so they can be tied in to the radio circuit.

5 **Attach your power source.** Now that your circuit is finished, all it needs is some juice. Use electrical tape to attach wires to the positive and negative sides of the battery. Then:

- Add the positive wire to any hole on the bottommost row of the breadboard to supply the black jumper and variable capacitor with current.
- Add the negative wire to any hole on the topmost row of the breadboard so it connects the speaker and the red jumper wire.[15]

6 **Listen to the speaker for noise.** Once the circuit has power, the electricity will begin to flow to the amp and the speaker. The speaker should now be making sound, though it might only be faint noise or static. This is a good indication that all of your components are correctly connected.

7 **Turn the variable tuner to adjust the frequency.** Turn the variable tuner slowly to shift the frequency your radio is reading and find audible radio stations. The further away from AM radio stations you live, the weaker the signals will be.

- Be patient and turn the knob slowly. With a little patience, it's likely you'll be able to pick up an AM radio station.

8 **Troubleshoot the circuit.** Circuits can be touchy, and many require troubleshooting, especially if this is the first circuit you've ever built. All leads need to be firmly inserted into holes, and each part of the circuit needs to be hooked up in the right fashion for it to operate.

- Sometimes you may have thought that you've pushed the lead all the way in to the board without it actually making a good connection.
- Adjust connections until you can hear audio when power is supplied. If this fails to work, you may need to rebuild the circuit from scratch.[16]

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Community Q&A

The variable tuning capacitor is not available. What do I replace it with?

wikiHow Contributor

You can't really replace it with anything unless you want to make your own.

Not Helpful 0 Helpful 4

How do I find a circuit diagram for a simple AM radio?

wikiHow Contributor

You can use images on the internet as long as you're able to read the circuit parts.

Not Helpful 6 Helpful 17

Could I use a wooden dowel to wrap the coils?

wikiHow Contributor

Yes, but it would lower the coil's self resonant frequency, though probably insignificantly. Meaning, the radio will tune to a slightly different frequency, yet without losing signal strength..

Not Helpful 0 Helpful 3

How do I do this without a breadboard? Is there even a way?

wikiHow Contributor

Yes, there is a way. You will have to solder the all the components together. It's not a good idea for newbies, though: the breadboard is a better option.

Not Helpful 5 Helpful 12

How do I boost the ability to receive signals on this device?

wikiHow Contributor

You can use more windings in your inductor, or get a variable capacitor with a larger range for more channels. (Most of the time the problem can be solved with more windings.)

Not Helpful 3 Helpful 6

Tips

- Keep positive if your circuit doesn't work on the first build. Circuitry projects are extremely temperamental, and you may need to practice building the radio several times before you get it to work.
- Check for faulty components. If you believe that your circuit is correct and all of the connections are strong, it's possible that some of your components are faulty. Capacitors, resistors, and op-amps are made very cheaply in large batches. Occasionally you'll get a faulty one.
- Buy a voltmeter to check connections. A voltmeter tests the current running through your components at any point in the circuit. They're inexpensive, and will help you know whether any of your components are faulty or if pieces aren't connected properly, in which case, current won't flow.

Warnings

- Do not overload your circuit with high voltage. Applying more than 9 volts to this circuit can cause your components to fail or catch fire.
- Avoid touching bare wires when current (electricity) is passing through the circuit. This will cause a zap, but because a low voltage battery is used in this design, it won't be serious.
- Do not connect the short lead of a capacitor to a positive voltage source. The capacitor will fail, usually with a small puff of smoke. In a worst case scenario, your components could catch fire.

Things You'll Need

- [ ] 1 megaohm resistor (x1)
- [ ] 10nF capacitor (x1)
- [ ] 15-20 in (25.4-50.8 cm) of red and black insulated wire
- [ ] 2,000 or 2,200pF variable tuning capacitor
- [ ] 22uF electrolytic capacitor (x1)
- [ ] 33pF capacitor (x1)
- [ ] 50-100 feet insulated wire (any color; for the antenna)
- [ ] 9-volt battery (x1)
- [ ] Breadboard

- [ ] Electrical tape
- [ ] Operational amplifier (also called an op-amp; x1)
- [ ] Small, non-conductive cylinder (glass bottle, cardboard/plastic tube, etc.)
- [ ] Speaker
- [ ] Wire strippers (or a similar item, like sharp scissors or a knife)

Sources and Citations

- Videos provided by Tommy Helgevold

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How to Build Several Easy Antennas for Amateur Radio

Amateur Radio has been a supreme way of communications for many ways of getting messages from one place to another for decades! Many antennas have been invented simply by necessity. Spark Gap Transmitters were used around the time of the great disaster of the Titanic. Wireless is what they called it back then, and still to this day, wire antennas are sending signals out on the airways. Amateur radio has progressed, and continually changed since the spark gap transmitters of that time. High voltage coils were used for their power, and it systematically sent out the familiar "dits" and "dahs" of Morse Code, and the party or parties, at the other end who could read Morse Code wrote the symbols down, and they made words. A fantastic, and fascinating way of communication, and yet, it was primitive enough to look back on from this date, and say that was one fantastic communications tool.

Steps

1 **Emphasis on the Antenna!** The heart of the system of Amateur Radio is the antenna. There are many other misinformed persons stating that power is the ultimate force. Not So ! The heart of any radio station, be it Amateur Radio, Commercial, Business, CB, Personal Family Radio, or experimenters in extremely low power amateur radio (QRP as it is called) transmissions IS the antenna! Without good reception, you won't hear much. Without good antennas for transmitting, you won't transmit far, even if you apply high output RF power, or if high output watts are used !

2 **Planning an antenna project can lead to many different thoughts and you should always consider the following.** Height, length, feedline, balun, (and we will talk about a balun later), insulators, type wire used, or type metal used, what do you want to do with this antenna, how many bands do you want it to perform its work, if you can use the right materials, space to hang one, and the biggest of all downfalls, if you live in a place that has zoning laws, you may have to get permission (gag) to put up an antenna on your own property !

3 **Use materials that match easily.** Antennas can be made from many different materials. Remember that you should use metal of similar nature, as dissimilar metals have a tendency to corrode, or to have a non-conductive properties. Metals such as copper, aluminum, tin, and steel all will conduct electricity, but when we are talking about Radio Frequency, or RF currents and voltages, we are talking about "Skin Effect" electricity. Aluminum antenna wire is hard to work with, has a very easy breaking point, and oft times, stretches out of shape, and cannot be soldered using conventional solder. Aluminum wire is not expensive, but it is the least desirable wire for antenna use. Copper house wire prices have skyrocketed in the recent months. Finding old house wire is the best choice. Diameter of 12 gauge wire is about 1/8th inch thick. Its not hard to work with, and is probably the best antenna metal. Tin wire, used for electric fence purposes make an excellent wire antenna, and it is not to expensive. The only draw back is that you have to purchase it in either ¼ or ½ mile (0.4 or 0.8 km) rolls. If you plan on building several antennas, you should have no problem with this large roll of wire.

4 **What Works with What Current.** Regular DC or AC current and voltages travel through the center of the wire, whereas RF runs on the outer portions of the wire. Picture if you will, a wire with the cut portion of the wire pointing at you. If we could see the wire with the current on it, it would be easy to define. AC and DC currents would be from the center out. RF though, would be along the outer portions of the wire, like the skin of the wire. The type of metal used would have a conductivity scale. Of course, none of us will be using any precious metals in making an antenna, but the rare metals, gold, silver, and platinum are the three most conductive metals of all, but since they cost so much, we have to settle for copper wire, steel with either a brass, or copper coating, or perhaps tin, with or without copper coating, or plain electric fence type tin wire, or possibly aluminum wire if you have no other wire to use. Any good conductor of electricity will conduct RF. The least favored is the mechanic wire, which has a high resistance, and corrodes and rusts easily, causing unwanted resistance, and antenna failure. When subjected to the weather, mechanic wire will rust easily, creating a never

ending problem of either breakage, or a problem of MAJOR non-connectivity. It does NOT radiate RF energy well, and doesn't receive signals from other amateur stations transmitting to you. One of the best, and probably the cheapest is the electric fence wire that is coated with brass, or copper. Since we are dealing with "skin effect" properties, just the outer coating will bear the RF energy. Steel wire also should be avoided if possible. Steel will rust easily, even if it is coated in brass or copper. Tin wire that is used for electric fence wire that is not coated, also can be used, but make sure that you inspect the connections from time to time to remove any corrosion, and re-solder them if necessary. Insulated house wire that is solid copper can make one fantastic wire antenna. At least seventy (70) percent of all amateur radio antennas are made of some sort of insulated, or non - insulated wire. Those are the ones we will be talking about here in this article.

5 **Start by choosing your place, and space for your antenna.** You should NEVER be close to a power line that is energized. Many people have been seriously injured or have been fatally electrocuted due to their contact with high power transmission lines. It takes just one touch from these high power lines to kill someone who is trying to put up an antenna. Look for low hanging power lines, and stay away from them at least by one and a half lengths of the height of your longest pole closest to the power wires. The closer you are to your radio room, the better off you will be. Back yard antennas, right close to your radio room, or radio shack, make it easy to set up and operate. Try to avoid placing any portion of your antenna close to the place where electricity enters your home. Use good straight wire, and avoid serious bends or twists in the wire. If you are using tin with copper or brass coatings, watch out for the tendency to coil back onto the wire. Some tightly wound wire may also coil back on itself, regardless of what it is made from, or coatings. Some wires also have a tendency of having sharp ends when cut. Steel is the worst. Good sharp side cutter pliers, or diagonal cutters can also leave a ridge that is sharp if using certain metals. The smaller the wire, the harder it is to work with also. Using wire of light gauge, either 17, 18, right through 22 or 24 gauge, has many problems, not the least of which is its durability. Wind can destroy an antenna in a few moves with small gauge wires 17 through 22. I recommend using not less than 18 gauge for most antennas. There are places, that we mentioned earlier, that won't allow antennas, towers or antenna poles to be constructed. A dipole in the attic of your home is a good idea if you have enough space in your attic to place one. Folded dipole antennas will work great if you do not have a metal roof.

6 **Select the wire you want to use.** Make sure it is a wire that can withstand the weather, both summer and winter, and that it is of a workable nature. In other words, don't use a wire that can cause problems down the road when it is actually put into use. Insulated copper house wire is excellent. Please! do NOT remove the insulation! As a matter of a fact, the life of the antenna can greatly be extended if you do leave the insulation on the wire. Also, it insulates it from a short against a green tree, or tree leaf, or even a weed, or branch that may fall. Make sure that if it is bare wire, that you keep it up from the ground, (and we will get into that also later) so no unsuspecting person comes in contact with the line, in the event it is energized with RF currents. RF burns can hurt, and burn deeply into the flesh of a finger or hand. RF is a sort of invisible energy, and it is the forced movements of electrons along a given path that is an AC style current.

7 **Many tuned circuits of today's time can actually go down to several layers of skin with just one touch.** It burns, and sometimes actually fries your skin into a white powder. This is called "RF BITE" since it feels like you got bit by some sort of bad bug, or stung by a bee that has no poison, but can seriously hurt. Amplified RF also hurts worse, due to the added power applied to the antenna. If you are using a tube type amplifier, depending on the wattage it has been tuned to, can and will give you one powerful bite,!, and it will hurt badly.

8 **Make your antenna by the tried and true formulas.** Dipole antennas often are the easiest to build, and then turned into inverted V antennas by raising the center of the antennas up into the inverted V style. It's a good idea to have your antenna at least one half (1/2) wavelength of the antenna. one quarter (1/4) wave is the minimum height above ground for effective performance. Wire "J" poles for VHF are easily built, and can be used in an emergency. These inventions simply use the ever popular 300 Ohm antenna lead in wire. You can use them for any frequency, including the HF bands, but you will need a tall tower, or a high tree to hang them high in the sky. As of this writing, 300 Ohm antenna wire is pretty scarce. A roll of 300 or 450 Ohm antenna wire was $55.00 just a year ago. Now if you can find it from any source, the same roll costs $95.00.

9

Here's several other feed lines you may consider to use. Choose which ever line fits your particular need. RG8 mini 8 can handle up to 2 kilowatts. RG8U, which is the large wire, with either foam or plastic center insulator and can be used up to 3 kilowatts, Hard line such 9913 series is the best for VHF or UHF transmissions. 300 Ohm covered ladder line is great if you have a long run, say more than 150 feet (45.7 m). Open feed line is trouble, but you can use it, IF IT DOESN'T act like like an antenna. If you cut open ladder line in less than a wave, it can act as your antenna instead of your radiator antenna element. Avoid using odd lengths of transmission line, and try to do the wave lengths version to prevent parasitic transmissions, and falling on your neighbors antenna, or bleeding off into someones cell phone, or perhaps even setting off home alarm systems that are close in your neighborhood. Car alarms that are not shielded can oft times be set off by using certain frequencies. Please take note here, if you are running amateur radio, and it's been checked out, it's NOT your fault that your neighbors are having problems. It's the poor design, shielding and the sensitivity of their equipment that is at fault. Sometimes, a solution can be reached, other times, there is no solution other than they have to put a filter, or a suppressor on their equipment to keep their equipment from malfunctioning, and acting as a receiver. The FCC also states that our equipment must not cause unwanted interference from occurring. In order to defend yourself, make note of the frequency you were using at the time the incident occurred, and if you have not had your equipment tested, have your equipment put on a spectrum analyzer, or a harmonic detector to PROVE your equipment is NOT causing any unwanted interference. If your equipment is clean, then it's up to the other party to take action to prevent them from getting on the ham band.

10 **Screen your VHF and MHF bands.** Some idiot kids are blaming amateur radio operators for their stupid mistakes. There are frequencies that we use that can cause malfunctions of their precious little toys, such as RC cars, airplanes and robots. Once again, its not the hams fault. It's mainly due to a flaw in design, shielding or it could be that their toys are acting as a receiver, and for that, they blame you. Such was a case not long ago, and we will discuss the outcome of that incident, but first let us talk building antennas.

11 **Maximum output!** What is maximum output.? The term Peak Envelope Power or PEP, is the maximum output power allowed by law peak to peak envelope, cycling from an AC source, RF output. With recent changes to some laws, the local government can also regulate how much power you can use. Legally, Amateur radio operators can run up to 1500 watts! That's a lot, but consider this, a ten thousand dollar set up with a 50 cent antenna, isn't gonna serve you well. Whether you live in the country, or in the city, the antenna is the root of good transmit / receive functions.

12 **Formulate then make!** The way to find out what length you need for a DIPOLE antenna, which is the most common antenna used, you use mathematical equation, 468/ FMhz whereas, 468 is the one standard, the fMHz is Frequency in MEGAHERTZ, and that give you the total length of a dipole antenna in feet. Divide by 2 and place a ceramic, dog bone, or even PCV pipe insulator between them in the middle where you just cut, and you got a dipole antenna. Attach a feed line, and run to your tuner, or if you are gonna use resonant antennas, attach to your SWR meter, and check for high SWR readings. Usually, less than a 1:5 to one or less is acceptable, but a 1:1 match reading is the very best. Using resonant antennas can be the most fulfilling experience of antenna use, however space and materials can pose a factor in using several antennas that are resonant to each band.

13 **Raising or lowering the antenna can help with SWR, but also one more thing to keep in mind, It's a good idea to raise the antenna at least 1/4th wavelength above ground.** Inverted V antennas can be tied off as high as possible, but can go as low as 3 or 4 feet (0.9 or 1.2 m) from the ground. Place a warning sign on the tie off point if your antenna is low enough to touch, telling anyone that high voltages can be present at any time, and not to touch the wire in any way.

14 **Stretch out the legs of the antenna as much as possible, and pull them as high in the air as possible.** The more capture area that is available, the better the transmit or receive. Secure line with good strong, nylon or rayon rope. Use either ¼ or ½ inch (0.6 or 1.3 cm) plastic nylon or rayon rope, and then you will find that these works best, but you should inspect them at least twice a year for frays, or weathering problems. Replace if necessary.

15 **Making a new design !** For many years now, designing antennas has been a passion for many a ham operator. The next one on the list is a cage dipole. For this, you will need either 4 or 6 inch (10.2 or

15.2 cm), thick wall PVC sewer, or water pipe, and a way to cut it in either ¼ or ½ inch (0.6 or 1.3 cm) spreaders. Use of a compound mitre saw makes this job easy. Use a 12" saw to cut the 6 and 4 inch pipes. WATCH OUT THOUGH, SINCE THE LAST FOOT OF THE PIPE COULD BUCK AGAINST THE SAW and may not cut through the pipe, and throw it back at you. Cut only where it will NOT be dangerous. usually 12 to 14 inches (30.5 to 35.6 cm) of the pipe will be left. If you own, or have a friend who owns one of the saws, use it to cut the pipes. Once they have been cut, measure the outside diameter of the pipe spreaders on the OUTSIDE in metric CM and MM. After you have the circumference, divide by 6 if you are using 6 wires, or divide by 8 if you plan on using 8 wires for this project. After you have the pattern down, use a drill with a 1/8th or a 5/32ths drill bit, depending on the gauge wire used to put 6 or 8 holes in each spreader. Be accurate as possible.

16 **Do not use the SAME FORMULA FOR THE CAGE DIPOLE.** It will be shorter than a regular dipole! It is relative to the size spreader used! You can only use the original formula as a starting point. Depending on spreader size you may have to reduce the length by as much as 4% or more!Just remember that you will either use 6 wires or 8 wires. Electric fence wire is often a choice in this type of an antenna, as it is relatively inexpensive, and can be bought in large rolls of one quarter or half mile or more wire on one spool. Tin wire will work in this project, however copper is best Using anything other than copper can compromise performance

17 **Measure carefully, although not critical at this point.** It's always better to go a little too long, than too short, and then have to add wire. Cut full run lengths of 6 or 8 wires. Its always a good idea to have a couple friends working with you when it comes to this project. Make the wires you have cut come together at the center when you have done your measurements.

18 **Assembling your antenna, and this where the fun comes into play.** Slide 5 spreaders on the wire, using 4 of them, easing them all the way down to the other end. Next, space the spreaders with the wires through the holes at intervals of either 18 or 20 inches (45.7 or 50.8 cm) apart. Put contact cement on the tooth picks, or match stems before sliding them into the holes with the wires to hold them firm. Leave one spreader at the first end, that way, it will show you where to place your wires into the spreaders. Continue with the spreaders, using 4 or 5 spreaders at a time, leaving one at the end each time. Tighten wire, and then peg the wires with the sharp toothpicks, or wood matches, using ONLY the wood on the matches. After you reach the end of one side of the cage, gather up all the loose wires at both ends, and tie them together using a piece of wire, wrapping all wire ends together near the center of the spreader. Lay this leg of the dipole aside, and do the same with the other leg.

19 **Make it "Count".** Whether you use 18 inch (45.7 cm) or 20 inch (50.8 cm) spacings in between the spreaders, to make it look good, don't change the spreaders in alternately positions. If you use 18 inch (45.7 cm) spacings, use them all the way to the end of the antenna. If you use 20 inch (50.8 cm) spacings, use all spacings at 20 inches (50.8 cm) apart. Larger wires in gauges of 14 or 12 can add weight to this project, so it takes a lot to get these antennas going. Don't rush this project! Take your time, do it right the first time, and then, you can rest assured that your antenna will serve your purpose. The capture area of a 6 wire cage dipole has increased 5 times ! An EIGHT wire antenna increases gain of capture by 7 ! Although it is hard to work with, and build this antenna, for amateur radio use, it's one of the best.

20 **ZOOM-XOOM-and Voila !** One of the best kept secrets of Amateur radio antennas are either the box, or delta loop antennas. Resonant antennas cut to the exact frequency, in the middle portion of the band, and used with a tuner of sufficient size, can tune several bands. The formula used to find a full wave loop antenna is 1005 / FMhz. This gives you the length of a full wave loop antenna for the band you are using. Horizontal positioning into a TRIANGLE shape, makes it a DELTA loop, If you put it into a square, or rectangle shape, you have a BOX loop antenna. Out in the country is where this antenna is most often used. It requires a large area of land, and also it can be fed either in the middle, or an end portion of the loop. When hoisting this little monster of an antenna into the air, watch out, as we said before, for POWER LINES~! Trees that are spaced far enough apart provide ample heights above ground for this antenna. Trees are often called, "Poor Mans Towers" and either can be accessed for use by using several methods, including a good fishing pole and a 4 ounce sinker, properly aimed at a high branch in the tree. When it is successful, tie a masons line, or even affix the rope you are going to use to the line, and gently roll in your catch over the branches of the tree, and pull it down to the ground. Don't forget to use adequate lengths of rope, or safety cord for this project. You can

use PVC pipe here as an insulator. Cut 3 or 4 pieces of 1 ½ inch (3.8 cm) PVC pipe about 6 or 7 inches (15.2 or 17.8 cm) long. Drill ½ inch (1.3 cm) holes using a good drill bit, and never drill close to the end of the pipe. About 2 inches (5.1 cm) from the end gives you a good spacing for the insulators. For the feed point, use yet another piece of PVC pipe, drilling a hole through the center to provide for a strain relief for the feedline. Put the stress on the pipe, not on the antenna or on the feedline. Pull up your antenna into the trees or your tower very carefully, making sure that it is as close as possible to the design you chose to make the antenna. Box or rectangle loop, or a triangle, spacing them out as much as possible. Yes, you can fudge a little if you have to on the sides, making one a little longer, but its best to keep your antenna as practical as possible to the design.

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Tips

- Strip carefully, tie the ground sections together, and solder to the negative side of your antenna lead in wire. All three wires should be soldered, and attached carefully.
- Get help with your antennas. Friends may find this experience fascinating.
- Measure twice, cut once. Although not critical in a cage dipole, it is highly critical to cut the exact length of an antenna to the band you are going to use
- Use wire of similar nature. Avoid using wires that corrode easily, or may break and lose conductivity.
- Locate your antenna as close as possible to your radio room to prevent loss of RF energy.

- It's fun to work the world on a wire. Antennas are the heart of any radio system.
- Using dull instruments for cutting wire may leave sharp edges that can pierce the skin easily. Check each end to keep sharp points from forming.
- Use PVC Pipe for cheap, easy insulators, and spreaders.
- Provide adequate space away from power lines.

Things You'll Need

- [ ] Antenna wire that is made from the choices above. Always get plenty of it.
- [ ] Good soldering irons, and rosin core solder.
- [ ] Knife, side cutting pliers, long nose pliers, stripper pliers, drill and proper size drill bits.
- [ ] PVC pipe in what ever diameter you choose to use for your antennas, and for your insulators.
- [ ] SPACE to hang your antenna in the air. Keep away from power lines.

Sources and Citations

- Consult any ARRL handbook for FAQs about antennas. Other pertinate information and articles from using diodes and resistors to control current, and useable information about antennas are listed there. Consult any ham radio operator about H.F. antenna construction.

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A mobile-agent-based wireless sensing network for structural monitoring applications

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A MOBILE-AGENT BASED WIRELESS SENSING NETWORK FOR STRUCTURAL MONITORING APPLICATIONS

Stuart G. Taylor[1], Kevin M. Farinholt[1], Eric B. Flynn[2], Eloi Figueiredo[1], David L. Mascarenas[2], Erik A. Moro[1], Gyuhae Park[1,*], Michael D. Todd[2], Charles R. Farrar[1]

1 The Engineering Institute, Los Alamos National Laboratory, Los Alamos, NM 87545, USA
2 Department of Structural Engineering Department, University of California San Diego, La Jolla, CA 92093, USA

E-Mails: sgtaylor@lanl.gov, farinholt@lanl.gov, eflynn@ucsd.edu, eloi.figueiredo@fe.up.pt, dmascare@ucsd.edu, gpark@lanl.gov, mdt@ucsd.edu, farrar@lanl.gov

* Author to whom correspondence should be addressed; Tel.: +1-505-663-5335; Fax: +1-505-663-5225

Abstract: A new wireless sensing network paradigm is presented for structural monitoring applications. In this approach, both power and data interrogation commands are conveyed via a mobile-agent that is sent to sensor nodes to perform intended interrogations, which can alleviate several limitations of the traditional sensing networks. Furthermore, the mobile-agent provides computation power to make near real-time assessments on the structural conditions. This paper will discuss such prototype systems, which are used to interrogate impedance-based sensors for structural health monitoring applications. Our wireless sensor node is specifically designed to accept various energy sources, including wireless energy transmission, and to be wirelessly triggered on an as-needed basis by the mobile-agent or other sensor nodes. The capabilities of this proposed sensing network paradigm are demonstrated in the laboratory and the field.

Keywords: Structural Health Monitoring, Wireless Sensing Network, Wireless Energy Transmission, Impedance Method.

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1. Introduction

Structural health monitoring (SHM) is the process of detecting damage in structures. The goal of SHM is to improve the safety and reliability of aerospace, civil, and mechanical infrastructure by detecting damage before it reaches a critical state. To achieve this goal, technology is being developed to replace qualitative visual inspection and time-based maintenance procedures with more quantifiable and automated damage assessment processes. These processes are implemented using both hardware and software with the intent of achieving more cost-effective condition-based maintenance. A more detailed general discussion of SHM can be found in [1].

The field of SHM is an integrated paradigm of networked sensing and actuation, data interrogation (signal processing and feature extraction), and statistical assessment (classification of damage existence, location, and/or type) that treats structural health assessments in a systematic way. An appropriate sensor network is always required as a first line of attack in observing the structural system behavior in such a way that suitable signal processing and damage-sensitive feature extraction on the measured data can be performed efficiently.

A specific topic that has not been extensively addressed in the SHM literature is the development of rigorous approaches to designing the data acquisition portion of SHM sensing system. To date, almost all such system designs are done somewhat in an *ad hoc* manner where the engineer picks a sensing system that is readily available and that they are familiar with, and then attempts to demonstrate that a specific type of damage can be detected with that system. In many cases, this approach has been shown to be ineffective and, as a result, researchers have begun to develop sensor networks suited for SHM. Based on this research, several sensor network paradigms for SHM have emerged.

This paper will first provide several sensor systems that have been used for SHM, along with a summary of their relative attributes and deficiencies. A new and hybrid wireless sensor network (WSN) paradigm, which has been investigated by the authors, is then presented. In this approach, both power and data interrogation commands are provided by a mobile-agent that is sent to

sensor nodes, alleviating several limitations of the traditional sensing networks. The mobile agent is a physically mobile WSN member, providing additional processing and power delivery support, and it should not be confused with a type of autonomous software referred to by the same name, which is characterized by its autonomy, learning ability, and mobility.

2. Current Sensing Network Paradigms for SHM Applications

The number of sensing systems available for SHM is enormous and these systems vary significantly depending upon the specific SHM activity. Two general types of SHM sensing systems are described below.

2.1 Sensor Arrays Directly Connected to Central Processing Hardware

A wired network telemeters data and transfers power to the sensor over a direct wired connection from the transducer to the central data analysis facility, which may or may not be on-site. Because this is the most common approach used for SHM studies, there are a wide variety of such systems. They can range in cost and complexity from a single peak-strain sensor to a custom-designed systems with hundreds of data channels and numerous types of sensors, costing multiple millions of dollars, such as the sensing system deployed on the Tsing Ma bridge in Hong Kong[2].

The advantage of a wired system is the wide variety of commercially available off-the-shelf systems that can be used for this type of monitoring. However, such systems are often difficult to deploy in a retrofit mode because they usually require AC power, which is not always available. Also, these systems are one-point failure sensitive with individual wires as long as a few hundred meters. Furthermore, system wires and cables can account for over 75% of the installation for larger scale structures, such as long-span bridges [3], and experience with field-deployed systems has shown that the wires can be costly to maintain because of environmental degradation and damage.

2.2. Decentralized Processing with Hopping Protocol

The integration of wireless communication technologies into SHM methods has been widely investigated in order to overcome the limitations of wired sensing networks [3, 4, 5, 6]. Wireless

communication can remedy the cabling issues with the traditional monitoring system and significantly reduce the maintenance costs. Wireless communication protocols are now standardized with such protocols as IEEE 802.11 through 802.16, and data transfer rates are now approaching those of conventional wired networks. Sensing, telemetry, and computing can now be performed on a single chip, reducing costs and permitting economically viable high-density sensor networks.

However, there are several technical challenges and requirements for wireless network applications caused by uncertain and often harsh deployment environments, as well as dynamic configuration demands. For example, the networks must be autonomously reconfigurable, meaning that each node, after deployment, must detect, identify, and locate its neighbor nodes. Of course, planned networks eliminate this challenge, but reconfigurable *ad hoc* networks are more robust because they can update periodically as both the environment changes or as nodes fail. Because there is no planned connectivity in *ad hoc* networking, the software must provide this information as necessary. As individual nodes receive neighboring information, they must intelligently fuse it with local information. Data fusion algorithms must be able to identify, classify, and accept or reject data packets all within the constraints of limited energy resources. Finally, the network, depending on the application, may have to deal with issues such as data security and seamless communication between mobile and stationary network devices.

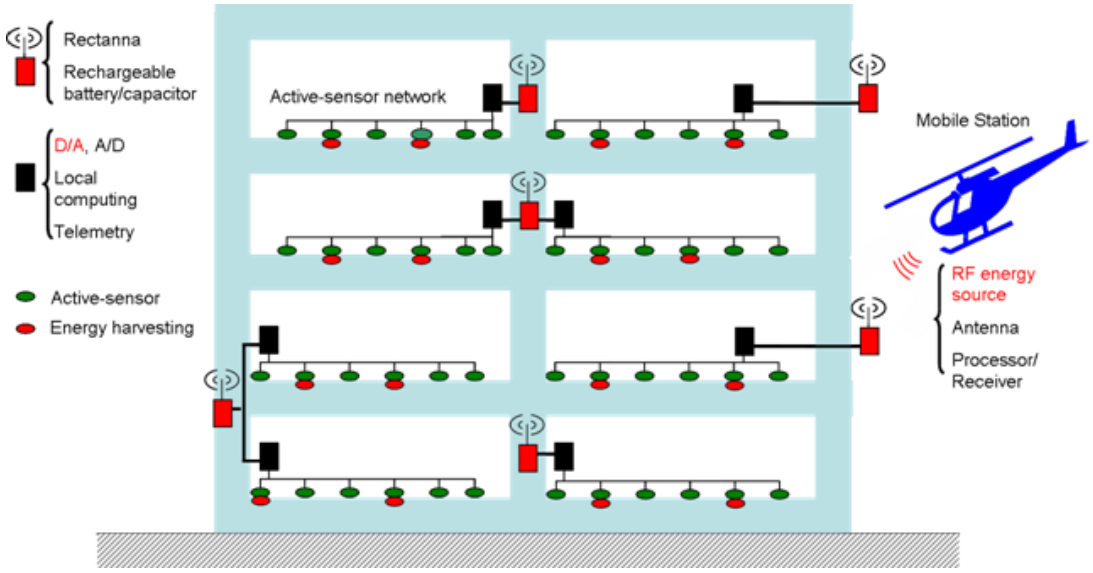
Another major consideration in deploying a dense wireless sensor array is the problem of providing power to the sensor nodes. This demand leads to consideration of information as a form of energy: obtaining information costs energy. In the absence of a direct power source, localized power generation technologies utilizing ambient energy harvesting may be used to power the instrumentation [7]. In this case, the amount of information desired must be carefully balanced with the amount of energy available. While there is tremendous research into the development of energy harvesting schemes for large-scale alternative sources such as wind turbines and solar cells, energy harvesting for embedded sensing systems is still in a development stage, and only a few prototypes exist for field-deployment.

3. Mobile-Agent based Sensing Network Paradigm

The sensing network paradigms described in the previous section have one characteristic in common. The sensing system and associated power sources are installed at fixed locations on the structural system. As stated, the deployment of such sensing systems can be costly and the power source may not always be available.

A new and efficient future sensing network is currently being investigated by the authors [8,9] by integrating wireless energy transmission technology and remote interrogation platforms based on unmanned vehicles, such as a robot or an Unmanned Aerial Vehicle (UAV), to assess damage in structural systems. This sensing network is shown schematically in Figure 1. This approach involves using an unmanned mobile-agent node (delivered via UAV or robot) to generate a power-providing radio-frequency (RF) signal near receiving antennas connected to the sensor nodes that have been embedded on the structure. The sensors measure the desired response at critical areas on the structure and transmit the signal back to the mobile-agent again via the wireless communications. This wireless communications capability draws power from the RF energy transmitted between the host and sensor node and uses it to power the sensing circuit.

Figure 1. A schematic of mobile-host based sensing networks.



The mobile-agent paradigm also supports a hybrid WSN configuration, with multiple localized sensor networks within a single structure or application. This hybrid networking approach would be useful in situations where the data from one network could be used by the mobile-agent to identify which network it should proceed to interrogate, following critical or catastrophic events. This approach would enable the mobile-agent to bypass certain networks to interrogate those which have the most pertinent data for emergency response or security personnel, particularly in circumstances where speed of response is essential to saving human lives.

It should be emphasized that this technology can be used in a hybrid configuration where the sensor node equipped with energy harvesting devices could be supplied supplemental energy by the mobile-agent. Even if the energy harvesting device provides sufficient power, the mobile-agent can wirelessly trigger the sensor nodes, collect information and/or provide computational resources, significantly relaxing the power and computation demand at the sensor node level.

4. Sensor Node Design

As this approach is a new sensing network paradigm, there is no off-the-shelf hardware readily available. Therefore, we developed wireless sensing hardware and associated sensors in this study. When designing these systems, particular attention was given to i) low-power operation, ii) wireless triggering capability, iii) wireless data transmission, and iv) interfacing with sensors with the required accuracy for SHM.

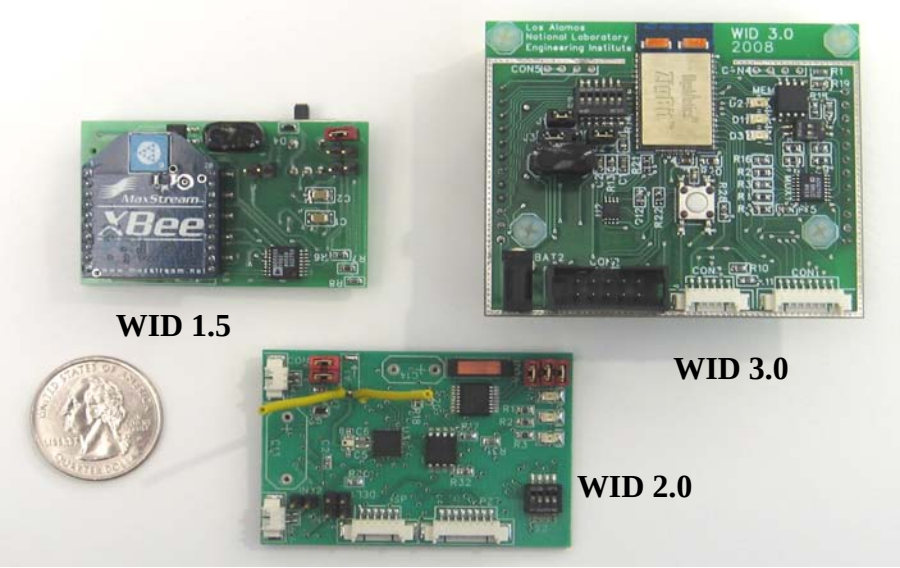
The wireless impedance device (WID) developed at Los Alamos National Laboratory (LANL) is designed specifically to monitor the electrical impedance (and conversely the admittance) of piezoelectric (PZT) sensor using the Analog Devices AD5933 impedance chip.

When bonded to a mechanical system, the electrical impedance of a PZT active sensor is directly coupled with the mechanical impedance of the structure. In SHM applications damage will manifest itself as a change or shift in the mechanical impedance of the system, which will then be reflected as a change in the electrical impedance of the piezoelectric sensor by the electromechanical coupling property of piezoelectric transducers [10]. This impedance method is utilized by the sensor nodes developed for this project.

The AD5933 impedance chip is capable of resolving measurements up to 100 kHz, a frequency range that is ideal for many SHM applications. The WID is designed to offer a low-power option for active sensing, operating on 2.8 V and drawing only 56mW of power during measurement operations, and 61 mW during data transmission. These operations typically require 5-10 seconds, after which the WID can be placed in a sleep mode where power consumption drops below 30 μW.

Several generations of the WID are shown in Figure 2, spanning from the first operational model WID1.5 to the most recent version WID3.0. Throughout the evolution of this hardware, several advancements have been introduced, including the ability to monitor up to seven PZT sensors per node, remote- and timer- based triggering options, as well as advanced telemetry components that have significantly reduced power needs. This hardware has been designed to operate with multiple power options, including the ability to store energy harvested from the environment or energy received through RF energy transmission. A more detailed description of this device can be found in the reference [11].

Figure 2. First three generations of the WID developed at LANL and UCSD



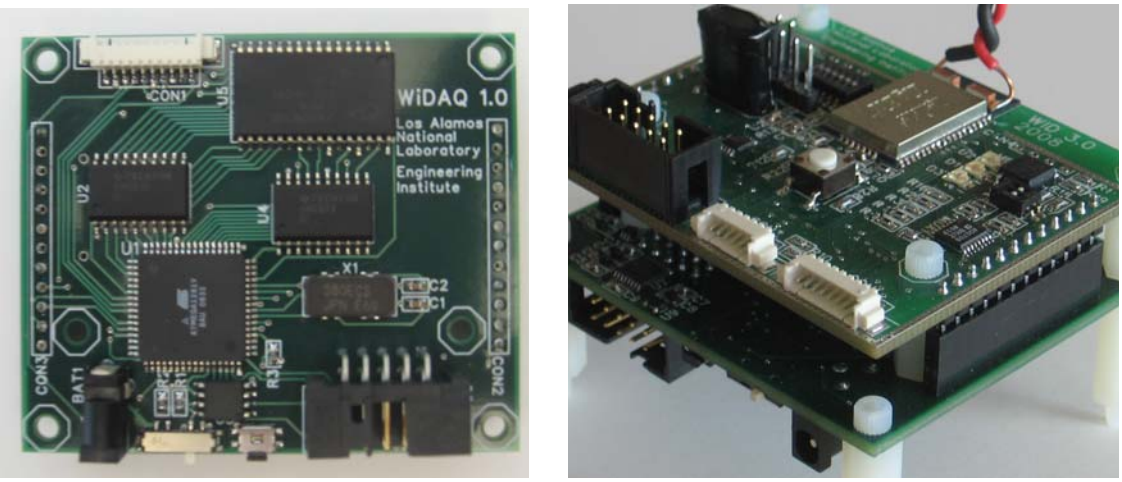
In addition to improving the capabilities and functionality of the previous WID versions, the WID 3.0 has been designed to function as part of a modular hardware platform consisting of both the WID and the Wireless Data Acquisition System (WiDAQ). The WiDAQ can function as a stand-alone device, and is controlled by an Atmel ATmega1281 microcontroller. The WiDAQ is shown in Figure 3. The WID 3.0 and the WiDAQ can share processing and data storage resources, and the WiDAQ utilizes the WID 3.0's telemetry capabilities to create a wireless data acquisition system.

The primary functions of the WiDAQ are data acquisition and signal generation. Sensor data can be acquired from any transducer that provides a voltage output using an Analog Devices AD7924 analog to digital converter. The four-channel AD7924 has a 12-bit resolution over a range from zero to 2.5 Volts, and it consumes a maximum of 6mW while sampling at one million times per second. The combined system with the ATmega1281 has a maximum useful sampling frequency of 40 kHz.

The WiDAQ is designed for both passive and active sensing. In addition to the AD7924, an Analog Devices AD5621 D/A converter provides the excitation signal necessary for active sensing using piezoelectric patches. The AD5621 has a 12-bit resolution with an output range of zero to 2.5 Volts, consumes a maximum of 0.5 mW and is capable of driving a 2kΩ load in

parallel with 1000 pF to ground. Each WiDAQ is capable of simultaneously providing an excitation signal through the AD5621 while measuring a response on each of the AD7924's four channels. However, the maximum sampling frequency of 40 kHz must be shared between the A/D and D/A converters. In order to achieve the maximum frequency with active sensing, multiple WiDAQs could be used together.

Figure 3. WiDAQ (left); Combined system of WID3 and WiDAQ (right)



5. Wireless Energy Transmission for Remote Powering Sensor Nodes

5.1 Background

A major challenge impeding the deployment of wireless sensor networks is developing a means to supply power to the sensor nodes in an efficient manner. The authors have explored possible solutions to this challenge by using a mobile-host based wireless energy transmission system to provide energy (in addition to data interrogation commands and computing power) to sensor nodes. The mobile-agent features the capability of wirelessly transmitting energy to sensor nodes on an as-needed basis. In addition, it serves as a central data processing and repository center for the data collected from the sensing network.

A pair of excellent survey articles were written to discuss the history of microwave power [12,13]. With the use of rectennas (antenna with a rectification circuit), efficiencies in the 50%-80% range of DC to DC conversion was achieved. Significant testing has also been done across long distances and with kW power levels [14]. Their study showed the feasibility of the energy delivery systems to actuate large devices, including DC motors and piezoelectric actuators.

However the application of this technology to low-power electronics has not been studied substantially in the past. In particular, the application of wireless power delivery for SHM sensor nodes in order to alleviate the challenges associated with power supply issues has never been addressed in the literature.

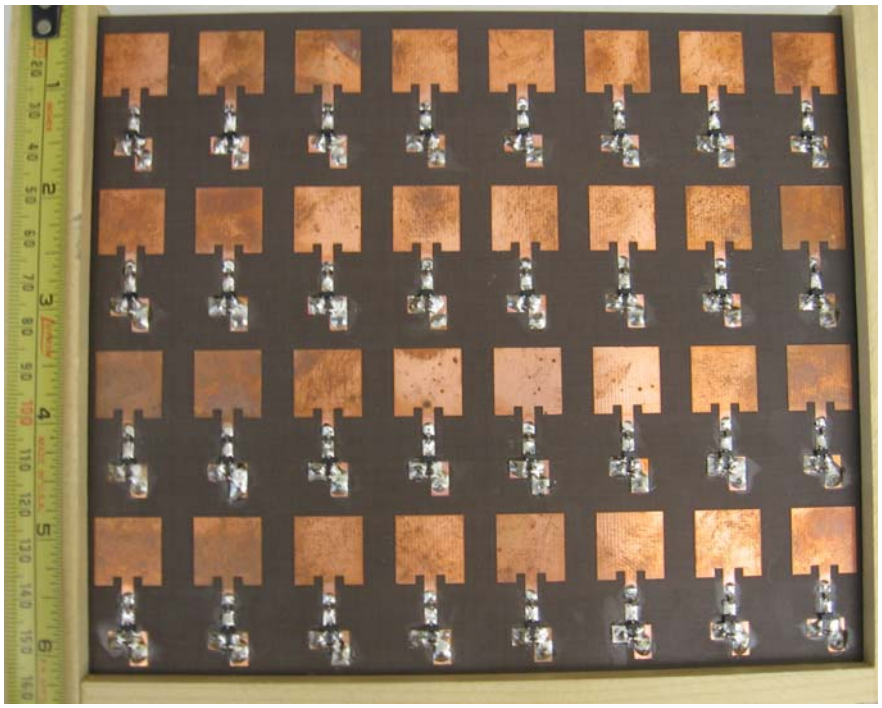
The wirelessly transmitted microwave energy is captured by a receiving antenna, transformed into DC power by a rectifying circuit, and stored in a storage medium to provide the required energy for the sensor node. In the RF data or energy transmission application, there are five principal components: an RF signal source, an amplifier and/or attenuator conditioner, a transmitting antenna, a receiving antenna, and conditioning electronics to process the received signal. There are numerous geometries for the transmitting antenna, providing directional or omni-directional broadcast capabilities. For our application a directional antenna was most desirable, and work has been performed with both the parabolic grid reflector and the Yagi-type antennas. The typical gain for these antennas is on the order of 15-24 dBi for the 2.4 or 5.8 GHz Industrial, Scientific, and Medical (ISM) band. For the present study a commercially available 5.8 GHz parabolic grid antenna was used as the transmitting antenna. This frequency was chosen in order to avoid possible interference with the data communication in the 2.4 -2.5 GHz ISM band being used by the telemetry of the sensor node.

In the design stage of this research, we focused on the development, fabrication and characterization of a microstrip patch antenna array that was designed to serve as our receiving antenna. To convert the received microwave energy into a DC signal the antenna is coupled with a rectifying circuit and a storage medium (typically a capacitor or battery) which collects the resultant energy. One of the limitations in microwave transmission is the attenuation of the wave as it travels through space. The loss associated with this attenuation has been characterized as the square of the distance between the transmitting and receiving antenna [15],as seen in the Friis transmission equation,

$$P_R = \frac{G_T G_R \lambda^2}{(4\pi R)^2} P_T , \tag{1}$$

where G_T and G_R are the transmitting and receiving gains, λ is the microwave wavelength in meters, R is the distance between antennas in meters and P_T and P_R are the transmitted and received power in milliwatts.

Figure 4. Thirty-two element, 5.8 GHz rectenna array designed at LANL



A microstrip patch antenna operates by creating a resonant cavity between a ground plane and a top plane of copper. The overall area occupied by the antenna is relatively small, on the order of 2.4 cm^2. While the individual antenna has a low associated gain, large arrays of microstrip antennae can harvest much more of the incident wave generated by the source antenna. The output of each individual microstrip patch can be connected in a variety of ways to tune the amount of voltage harvested from the array. An example of a thirty-two element microstrip patch antenna array is shown in Figure 4.

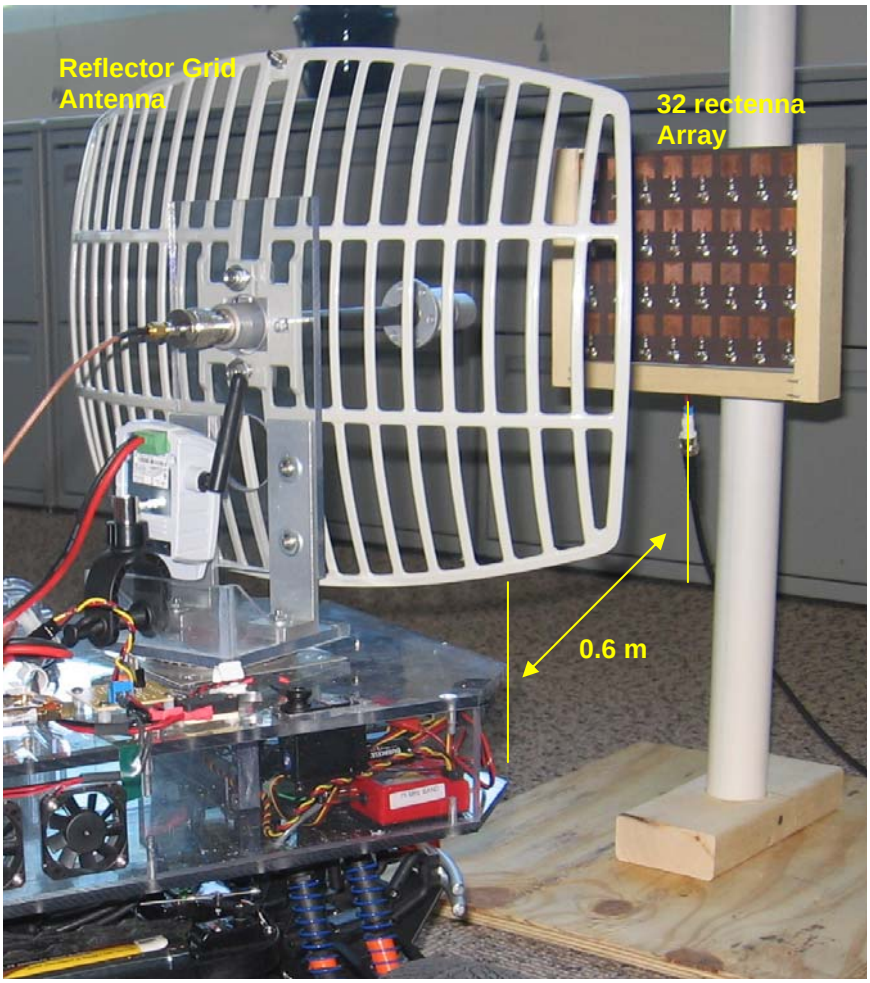
5.2 Experimental Results

Laboratory experiments were designed to evaluate the power efficiency of the prototype rectennas developed in this project, and to demonstrate that they could feasibly be used to power one of the low-power SHM sensor nodes. A reflector grid antenna was used as the source antenna, and was driven in the 5.8 GHz band through a RF signal source and a power amplifier. The output power was limited to 1 W for laboratory tests. The energy is received by the thirty-two element rectenna array, located 0.6 m away. The experimental set-up used in the laboratory tests is shown in Figure 5.

Testing was conducted to charge a 0.1 F capacitor to 3.5 V, which corresponds to the operating range of the WID sensor node. The voltage accumulation within the capacitor was monitored throughout the charging cycle, and the resulting charge time history is plotted in Figure 6. The result indicates that it takes approximately 40 seconds to charge the capacitor. These results compared favorably with the commercial panel antennas that were tested, which typically take at least a minute to charge the same supercapacitor.

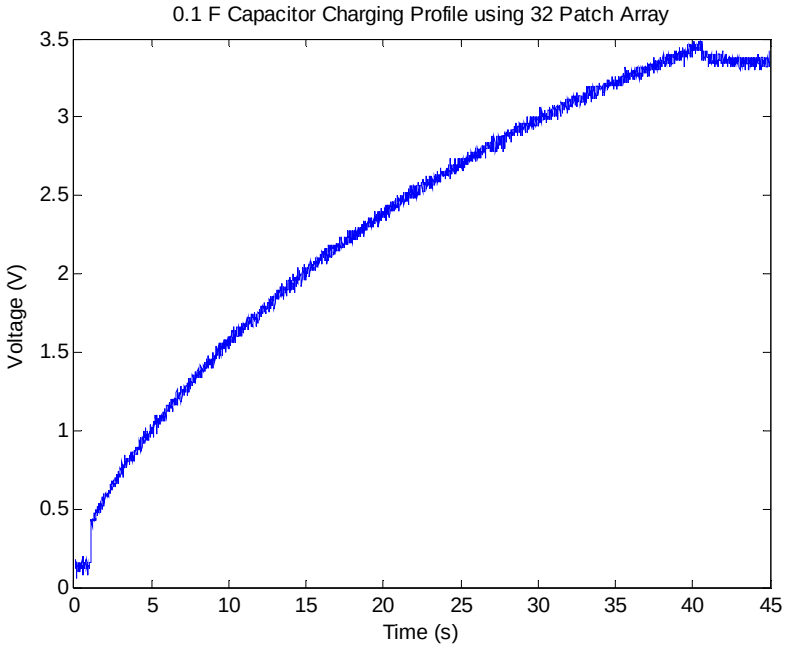
The sensor node is equipped with a power conditioning circuit that was designed to prevent the WID from being turned on until the voltage had reached 3.5 V. As the capacitor reaches the critical voltage of 3.5 V, the WID is powered on, measures the electrical impedance from two PZT sensors, and relays this data to a base-station located several meters away.

Figure 5. Laboratory experiment designed to test the thirty-two element rectennas



Wireless energy transmission has promise as a suitable solution for providing power to the proposed sensor node or any other (long-term) wireless sensor nodes. The advantage of this transmission system is that power does not have to be embedded with the sensing system, but transported to its vicinity and then wirelessly transmitted to the sensor node. It is anticipated that such a sensor network will have improved reliability and will have inherent advantages when monitoring must be performed in locations that are physically difficult to access. It is anticipated that these systems will evolve to hybrid systems that couple local energy harvesting at the node level with the RF energy delivered by the robotic vehicle.

Figure 6. Laboratory results taken using the mobile-agent and the 32-patch array in close range to charge a 0.1 F capacitor.

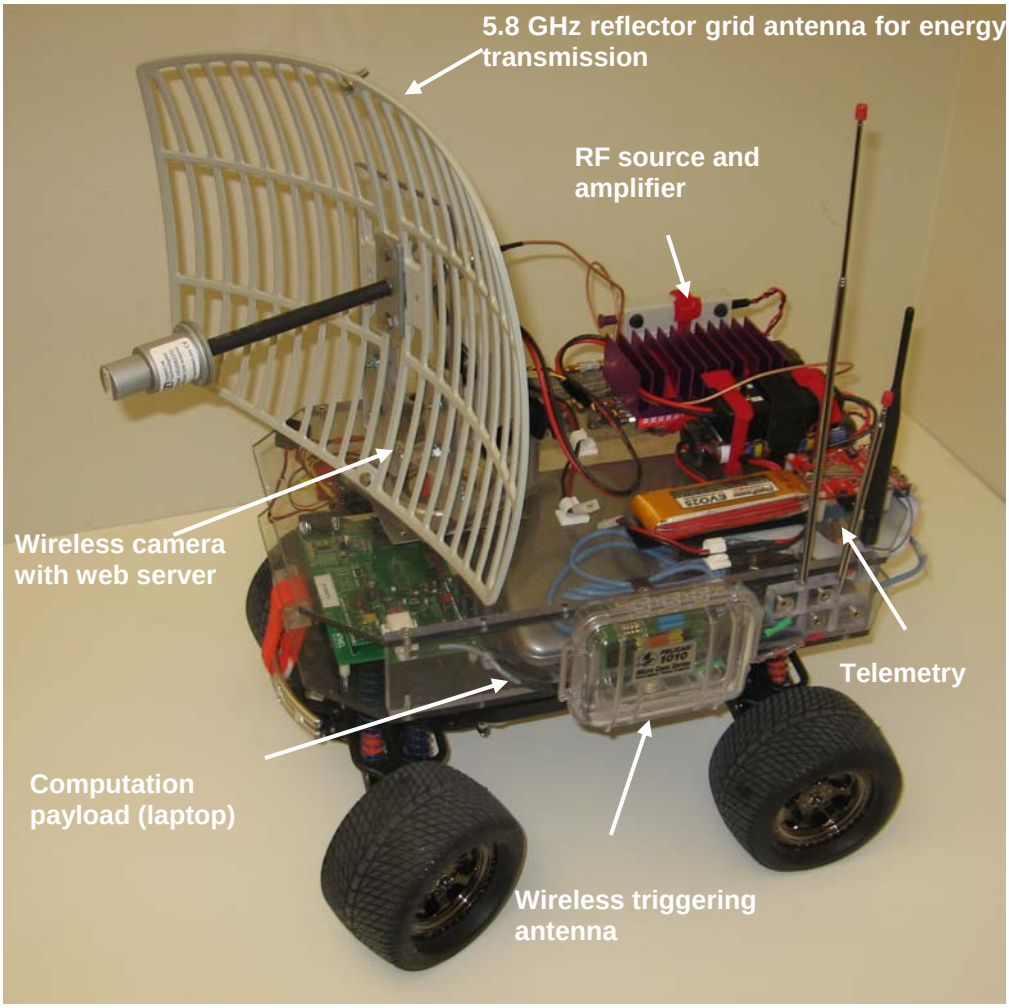


6. Mobile-Agent Design

The mobile-agent used in this paper is a battery powered remote controlled (RC) vehicle. The vehicle weighs approximately 5 kg and carries the required components needed to implement the mobile-agent based SHM process.

The computing source on the vehicle is provided by a laptop computer running a Windows XP operating system. This computer is remotely accessed from the base station, allowing command and control of the computer and RF source from the base station via 802.11g wireless network. The SHM software is installed on this computer to make a real-time assessment on the structural condition, which will be detailed in the next section. Data are received from the sensor node via an RS-232 enabled Meshnetics modem. The data are stored in the computer hard drive until requested by the base station. The vehicle can also wirelessly trigger the sensor node using a low frequency RF triggering antenna installed on the side of the vehicle. The triggering command is sent from the base station to the mobile computer, and the command is executed via an RS-232 connection, sending a wake-up 125 kHz RF wake-up signal to the sensor node.

Figure 7. The mobile-host RC vehicle and its component



This vehicle also hosts a NovaSource G6 RF signal generator. This RF source signal is sent through a Stealth Microwave RF amplifier that increases the output power to levels that suitable for wireless power transmission (~1 Watt). Each of these components is also configured to be controlled remotely from the base station. For energy transmission, a parabolic grid antenna is mounted on the front of the vehicle. The mobile-agent also carries an Axis 207W wireless webcam for recording events as seen by the vehicle. The RF/Computational payload is powered

by two separate Lithium-Polymer batteries. Figure 7 shows the various components on the vehicle.

7. Software Integration

One major advantage of the mobile-agent paradigm is the ability to bring relatively high power and highly flexible computing to the sensor network for on-site SHM computations. The foundation of the software system is made up of self-contained, single-purpose blocks of code which we refer to as modules. At a base station server, the user assembles these modules to form SHM processes and then ports these processes to the roving host client for on-site execution. Here we describe in further detail each of these three primary elements.

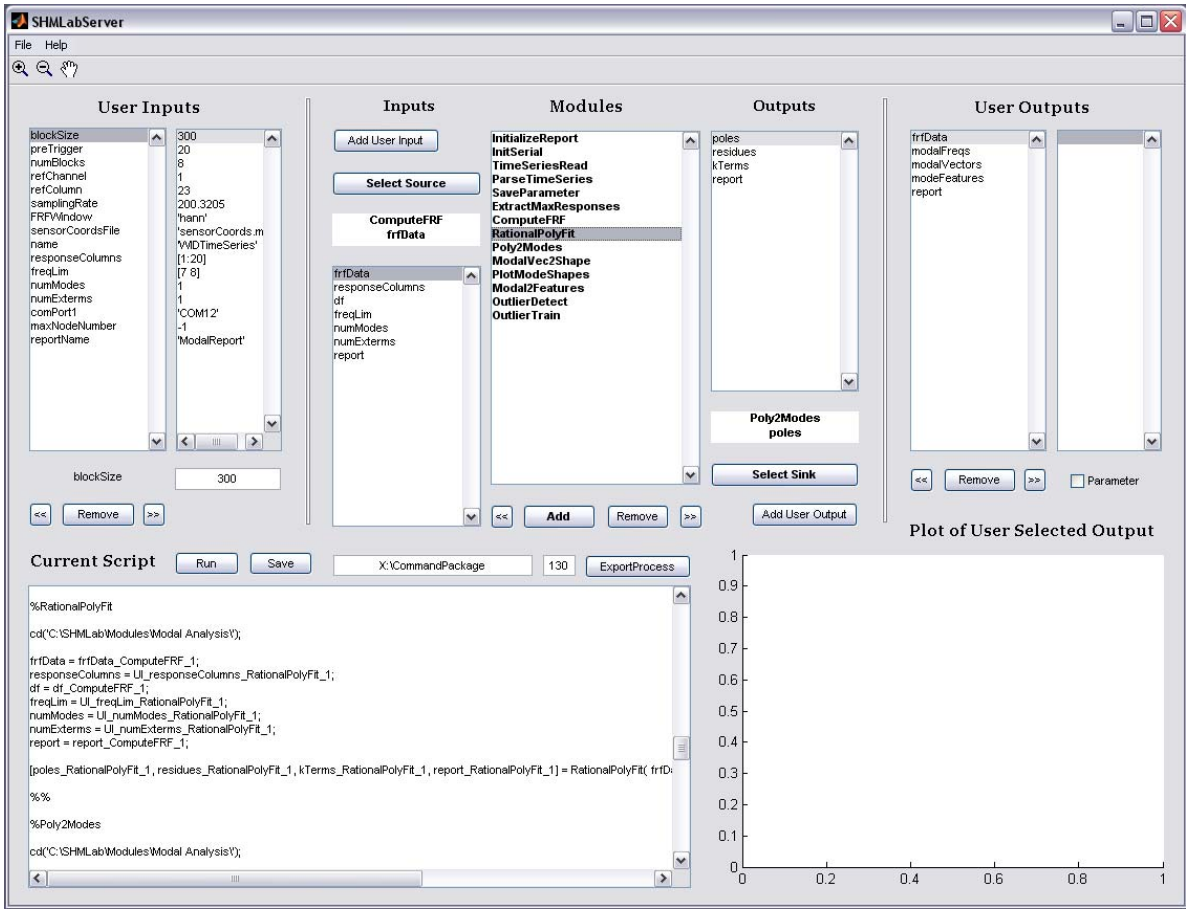
7.1 Modules

Each module is designed to perform a single, self contained task, and follows an established set of data formatting standards. The established data standards and a built-in flexibility within the modules eliminate the need for any intermediate code, allowing for rapid algorithm development. For this study, we developed a library of modules for data acquisition, feature extraction, feature classification, and report generation.

7.2 Base Station Server

At the base station server, through a simple interface, modules are graphically assembled together and parameters are linked from one module to the next to form a linear sequence. A generic wrapper function, which manages the parameter passing, is built automatically from this arrangement and a set of links. After the sequence is constructed, the user can test the sequence and tweak user-defined inputs through simulation of the roving host environment. When the testing is complete and the desired input parameters are established, the server uploads the sequence and parameters to the roving host before it is released to the field. A snapshot of the module assembly process is shown in Figure 8. The automatic code generation of the sever, along with the flexible modules, allows for rapid prototyping, deployment, updating of an SHM process, and roving host turn around.

Figure 8 A snapshot of the module assembly process in the base station. The assembled modules can be dynamically exported to a mobile station.



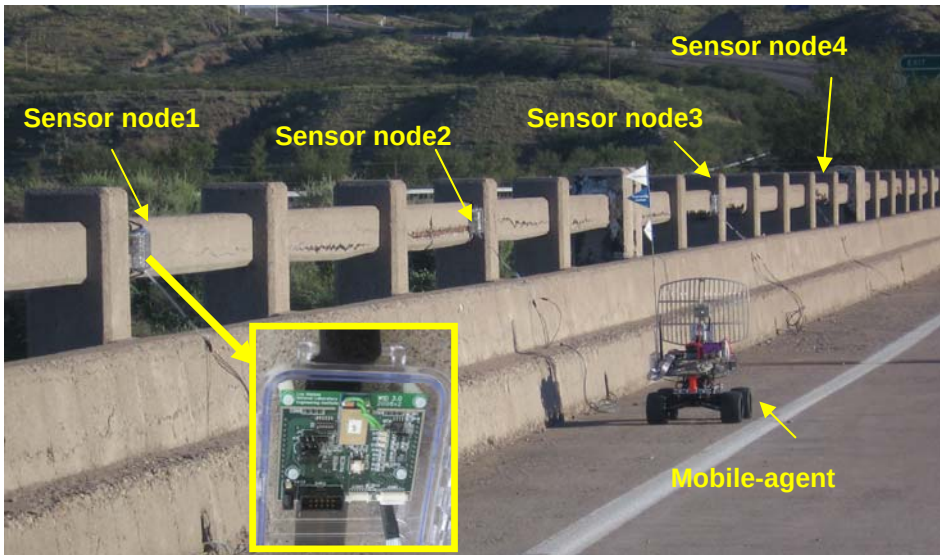
7.3 Roving Host Client

At the roving host client, the downloaded sequence is initiated by an external trigger. This trigger may be from the roving host's navigation system, a remote user (if communication is possible), or the sensor node itself. The modules in the sequence then perform the tasks of establishing communication with the sensor nodes, requesting and receiving data from the nodes, processing the data to extract relevant features, classifying the data, and updating the classification model. Each module, in order, stores any relevant data to file and updates a single running html report, providing the results of its individual task. Upon the roving host's return to the base station, the full report and all data files are uploaded to the base station server for viewing and possible further processing.

8. Experimental Verification at the Alamosa Canyon Bridge

The first field test of the proposed sensing network was performed on the Alamosa Canyon Bridge in the southern New Mexico, USA. The bridge is a traditional steel girder bridge with a reinforced concrete deck 25 cm thick. This bridge has been decommissioned and is utilized by the New Mexico State Department of Transportation as a test bed for structural health monitoring systems from university and research organizations. First, the wireless triggering capability of WID by a mobile-agent is shown in bolted joint monitoring of the bridge. Second, following the successful operation of the WID exclusively from RF energy as demonstrated in the laboratory, a series of field experiments were developed to further test the system's performance under more rigorous operating conditions. Next, hybrid networking capabilities were demonstrated as the mobile-host as it traveled to different local networks to collect the data from each one. Finally, the capability of the combined WID and WiDAQ system to measure the low-frequency vibration data of the bridge under impact loading was demonstrated.

Figure 9. Layout of the field test conducted at Alamosa Canyon Bridge, NM.

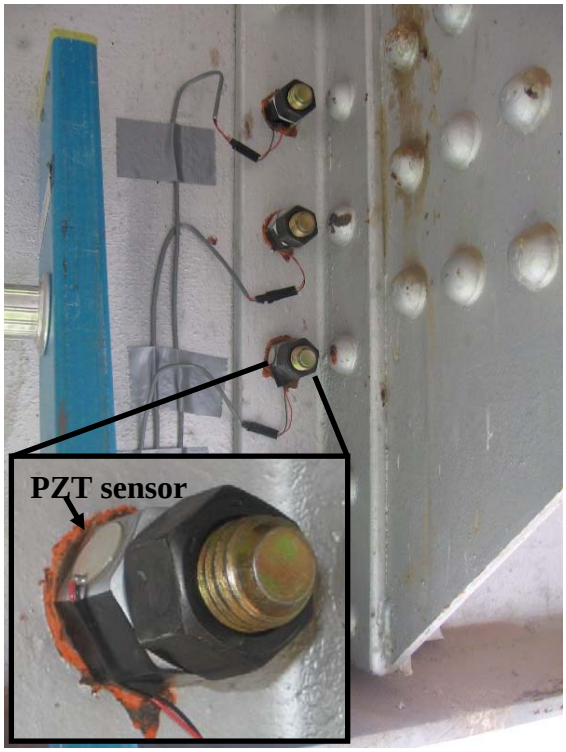


Eight sensor nodes were mounted along the longitudinal rail of the bridge. Four sensor nodes installed along the east side of the bridge are shown in Figure 9. The nodes were spaced at intervals of 5 meters. The sensor nodes were mounted on top of the deck for ease of access, and each sensor node was connected to three instrumented washers below the deck that were mounted using steel bolts (19 mm diameter) to secure a steel cross member to the outer girder of the bridge. A series of three instrumented washers is shown in Figure 10, with an exploded view

of an individual washer clamped between the girder and the steel nut. The tightness of these components was varied throughout the experiment to test the sensor node's ability to identify the state of each instrumented bolt mounted on the bridge. All the sensor nodes were configured to be wirelessly triggered by the low frequency RF signal, which would be initiated by the mobile-agent vehicle.

The operating principle of the PZT instrumented washer is described here. These washers are used in the same manner as their conventional counterparts. If these devices are mounted in a structure, the dynamics of these washers will be changed as the preload is changed. More specifically, the resonant peaks of the device would all shift to slightly higher frequencies, and then, at a certain threshold level of tightness, the magnitude of the peaks would drop substantially until the magnitude would almost disappear. These changes can be efficiently monitored by the impedance method and WID. More detailed discussion on this principle can be found in the reference [16].

Figure 10. Instrumented bolts mounted to the girder of the Alamosa Canyon Bridge. Preload was monitored with the PZT sensors using WID sensor nodes.



8.1 Wireless Triggering Test

For this testing, the remotely controlled mobile-agent approaches the sensor node and establishes a range of 3 m between the RF triggering antenna installed on the side of the vehicle (shown in Figure 7) and the sensor node. The triggering command is sent from the base station, which monitors the movement of the vehicle through the wireless video camera mounted on the mobile-agent. The computer inside the vehicle receives this command and executes it by sending a 125 kHz RF wake-up signal to the sensor node. The sensor node is brought out of its sleep status by this signal, takes the measurements from the piezoelectric sensors, locally determines the magnitude of the resonance of each sensor, and broadcasts the data to the mobile-host vehicle. The laptop computer inside the RC vehicle receives and processes these data to make the decision on health-assessment conditions of each joint. The entire process is also passively monitored by the computer at the base station.

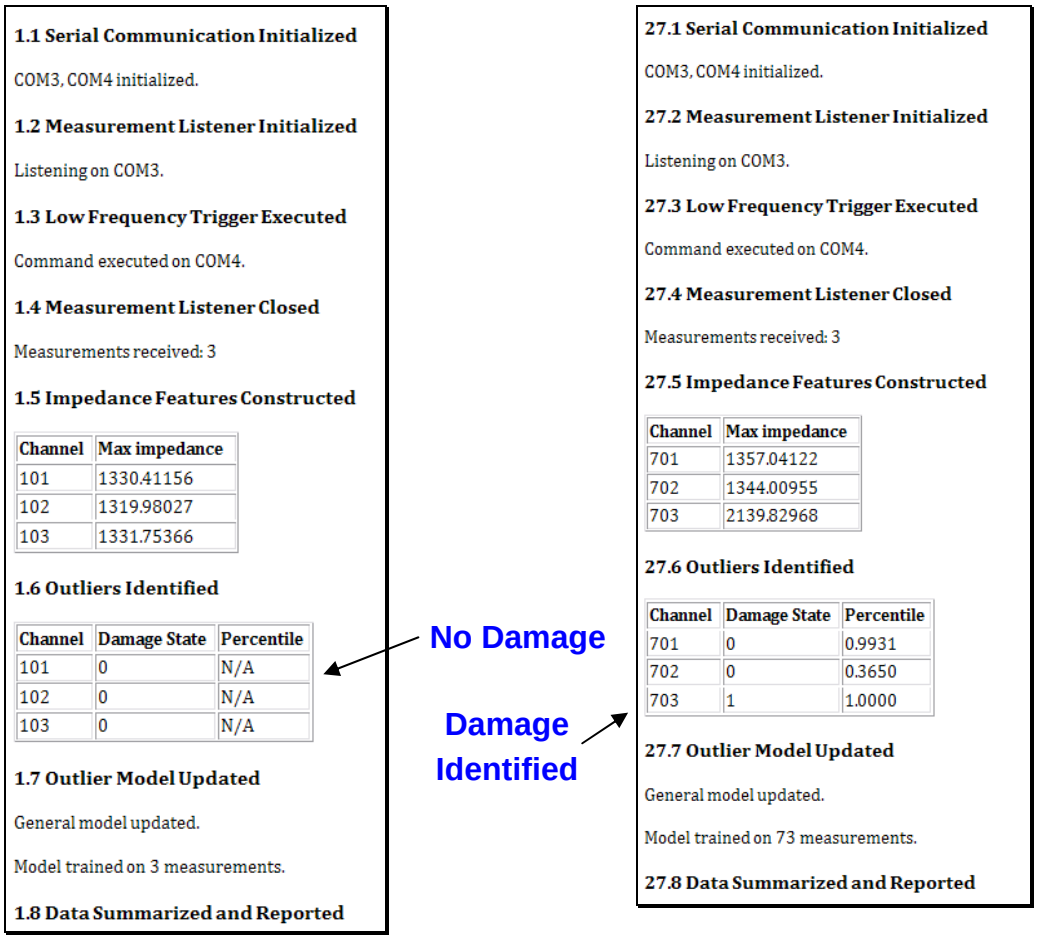
The WIDs were programmed to monitor the peak magnitude of the washer in the frequency range of 51-53 kHz and, it was configured to be triggered by the low frequency signal. For the mobile-host, data are wirelessly received through the Zigbee RF telemetry module that was used as a serial port interface. Several software modules were written for importing and processing data from the serial port.

For the first test, all the bolts connected to each sensor node were tightened to 240 in-lb of torque. The mobile-host vehicle then moves close to each sensor node, wirelessly triggers the nodes, and receives and processes the data. On the mobile-agent's first passes through the sensor network, collected measurements were used to build and update a running probability density model. A snapshot of the report as generated by the mobile-host for the first interrogated node is shown in Figure 11. Each sensor shows three data points that correspond to results from three piezoelectric sensors connected to a node. Note that the outlier identification has no significance until a sufficient model has been built up.

After the mobile-host made several passes through the network, damage was introduced by loosening one bolt (out of three) to hand-tightened for joints connected to the sensor nodes 7 and 8. Figure 11 also shows a snapshot of the report resulting from the interrogation of sensor node 7. The mobile-host reported a significant increase in the maximum impedance on the third bolt

and correctly identified it as an outlier. The percentile is an estimate of the fraction of the number of measurements expected to have a higher local probability density than the current measurement based on the probability density model. Thresholds were chosen by the outlier model trainer to correspond with a 95% confidence level. Using this interrogation process, all damaged joints were identified with a 100% detection rate and 0% false alarm rate.

Figure 11. Reports generated by the mobile-agent

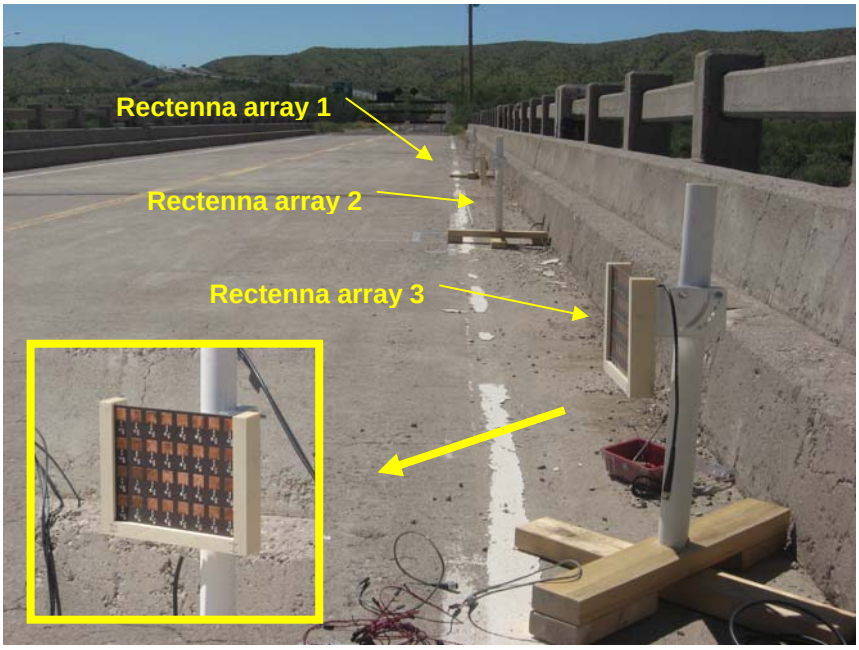


As shown in this example, using the mobile-agent, the structural health assessment can be made very quickly in an entirely wireless manner. This approach could alleviate several problems of traditional *ad-hoc* and hopping networks, such as data collision and communication failure in the node level [17]. Furthermore, this technology may be adapted and applied to damage detection in a variety of other civilian and defense-related structures such as, nuclear power plants where it is advantageous to minimize human exposure to hazardous environments during the inspection process.

8.2 RF Energy Transmission

For wireless energy transmission, three sensor nodes on the west side of the bridge were re-configured to take measurements and transmit data once powered on by the wireless energy transmission system. For the WID3, a power conditioning circuit was implemented, which allows the capacitor to charge to a predefined voltage of 3.5V before sending power to the WID. The microstrip patch antenna array mounted near a sensor node is shown in Figure 12.

Figure 12. Rectenna arrays used for powering WID at the bridge



The energy transmission equipment was mounted within the mobile-agent vehicle as shown in Figure 7. The RF source was configured to emit 1W of energy at 5.8 GHz and was positioned to transmit over a distance of 0.5 m. This RF transmission system was also remotely operated by the driver of the vehicle from the base station, and the system was turned off once voltage was supplied to the sensor node. Multiple experiments were performed using this system as the vehicle was driven up to the rectenna where the vehicle was stopped and energy was beamed to the receiving antenna. The setup of this testing is shown in Figure 13.

Figure 14 depicts the charging profile within the 0.1F supercapacitor as the RF energy was being transmitted. The system was capable of charging the capacitor to a voltage of 3.5V in an average time of 50 seconds at a distance of 0.5 – 0.7 meters. The plot indicates that it took about 10 seconds longer than the results obtained from the laboratory. The change in performance could be due to a less than ideal alignment between two antennas in the field. In this figure the wireless transmission was initiated at 2 seconds and approximately 50 seconds later, the power conditioning circuit is triggered, causing the sensor node to become active and take a measurement of the piezoelectric sensors, as indicated by the sharp drop in voltage at 52 seconds. The voltage then stabilizes as the microcontroller performs local computations, at which point the sensor node transmits the data to the mobile-agent as indicated by the sharp drops in voltage.

Figure 13. Setup of RF transmission at the bridge.

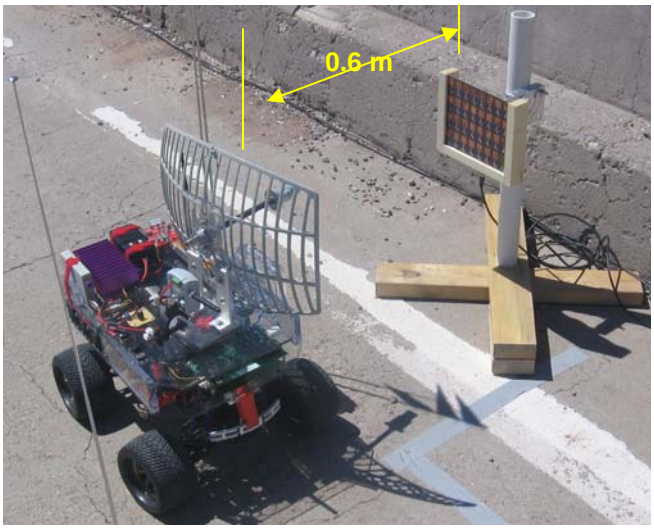
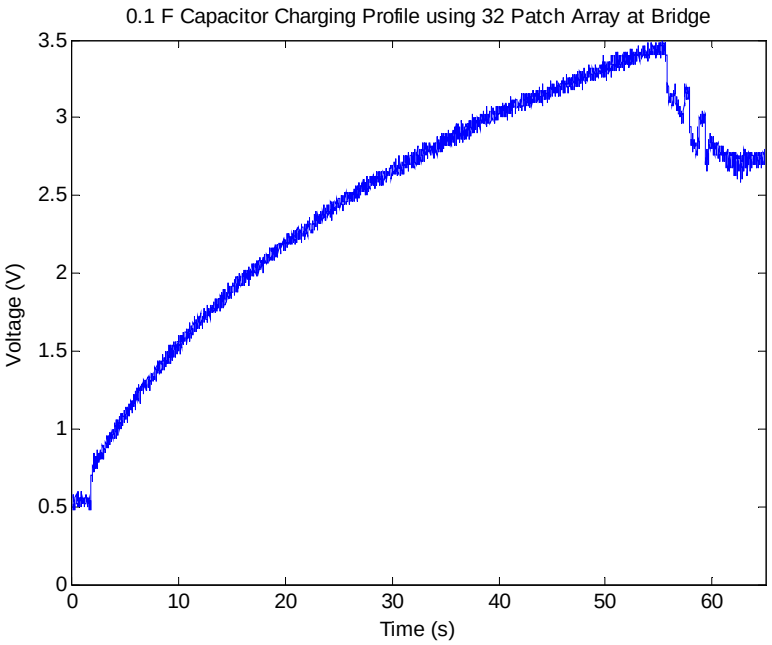


Figure 14. The results taken from using the mobile-agent and the 32-patch array to charge a WID sensor node at the bridge.



This study provides an excellent opportunity to demonstrate the feasibility of the mobile-host based wireless sensor network. By using the wireless energy transmission, the sensor nodes do not have to carry on-board power sources, and the required energy can be delivered on an as-need basis. This technology will be directly applicable to rapid structural condition assessment of buildings and bridges after an earthquake where the sensor nodes may need to be deployed for decades during which conventional battery power would be depleted.

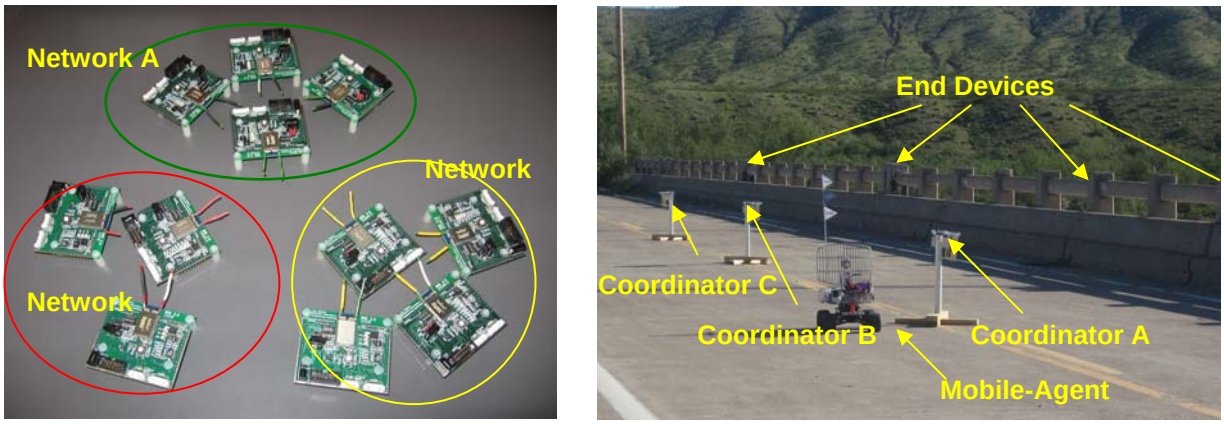
8.3 Local Network Association Test

The local network association test simulates a permanent installation of WIDs for continuous automated monitoring of large-scale structures, using three separate local networks to demonstrate the hybrid networking capabilities of the WSN. The schematic of the local network is shown in left-hand image in Figure 15. Maintaining separate local networks has several advantages with very large structures in that additional routers to transmit data over large distances are not required. Furthermore, immediately following a catastrophic event, the loss of a single node could not destroy the entire network. This networking approach is more efficient

with active-sensing SHM techniques, as those techniques are local area monitoring techniques, as opposed to global structural monitoring systems.

Three separate local networks were implemented on the bridge, each operating using a different frequency band. Each coordinator was constantly powered, and the end devices operated in an extremely low-power mode, awakening at regular intervals to take measurements, and transmit the results to the coordinator. The coordinators stored received measurements on non-volatile until the data were retrieved by the mobile-agent. The setup of this testing on the bridge is shown in the right-hand image of Figure 15.

Figure 15. (left) Separate local networks schematic; (right) Mobile-agent approaches coordinator A to retrieve data from network A.



This local network approach is somewhat unique for SHM applications, as SHM sensors and sensor nodes do not have to be deployed on to the entire structure. Instead, the nodes could be installed on critical areas of a structure, following the concept of the active-sensing SHM strategy. The sensor node does not have to attempt to identify any neighbor nodes or relay the data, as in the case of the hopping networking protocol. Furthermore, the sensors can be more optimally placed on a structure to improve the performance of the SHM process. The authors are currently investigating the feasibility of using the mobile-agent as a "communication bridge." Each local network operates as described above, and if needed, the mobile-agent executes a command to coordinators in the range to instantaneously construct a "global" network from each local network. In such a way, low-frequency global monitoring, as well as active, local monitoring could be readily performed.

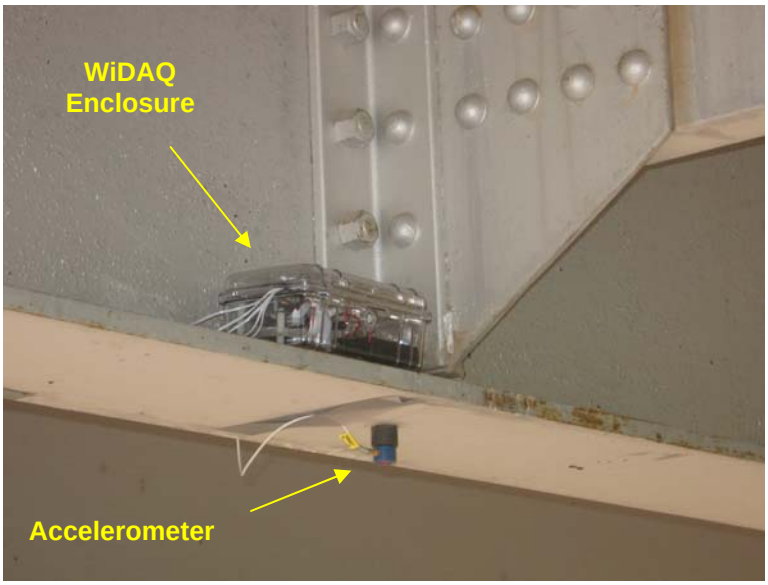
8.4 Low-frequency Vibration Acquisition Test Using WiDAQ

The final testing was done by taking the low-frequency vibration data of the bridge using WiDAQ. Before the test, a traditional data acquisition system was used to measure the data for comparison purpose. The test procedure was essentially the same as the one performed previously [18], and briefly described below.

The data acquisition system was set up to measure acceleration and force time histories and to calculate frequency response and coherence functions. Sampling parameters were specified that calculated the frequency response functions (FRFs) from a 16 second time window discretized with 2048 samples. The FRFs were calculated for a frequency range of 0-64 Hz at a frequency resolution of 0.0625 Hz. A PCB model 086B0 impact sledge hammer was used to provide the excitation source. The sensor in the hammer had a nominal sensitivity of 0.169 mV/N and a peak amplitude range of 22300 N. A specially designed hammer tip was used to broaden the time duration of the impact, and hence, better excite the low frequency response of the bridge.

PCB model 336C piezoelectric accelerometers were used for vibration measurements. These accelerometers have a nominal sensitivity of 1 V/g, a specified frequency range of 1-2000 Hz, and an amplitude range of +/- 4g. All accelerometers were mounted to the bottom flange of the steel girders using PCB model 080A05 magnetic mounts. A total of 20 acceleration measurements were made on the girders below the bridge and at the excitation point, which was located on the top of the concrete deck. The experimental procedure, sensor locations, and the excitation point can be found in the reference [18].

Figure 16. WiDAQ installed on the bridge girder to measure the response from accelerometers



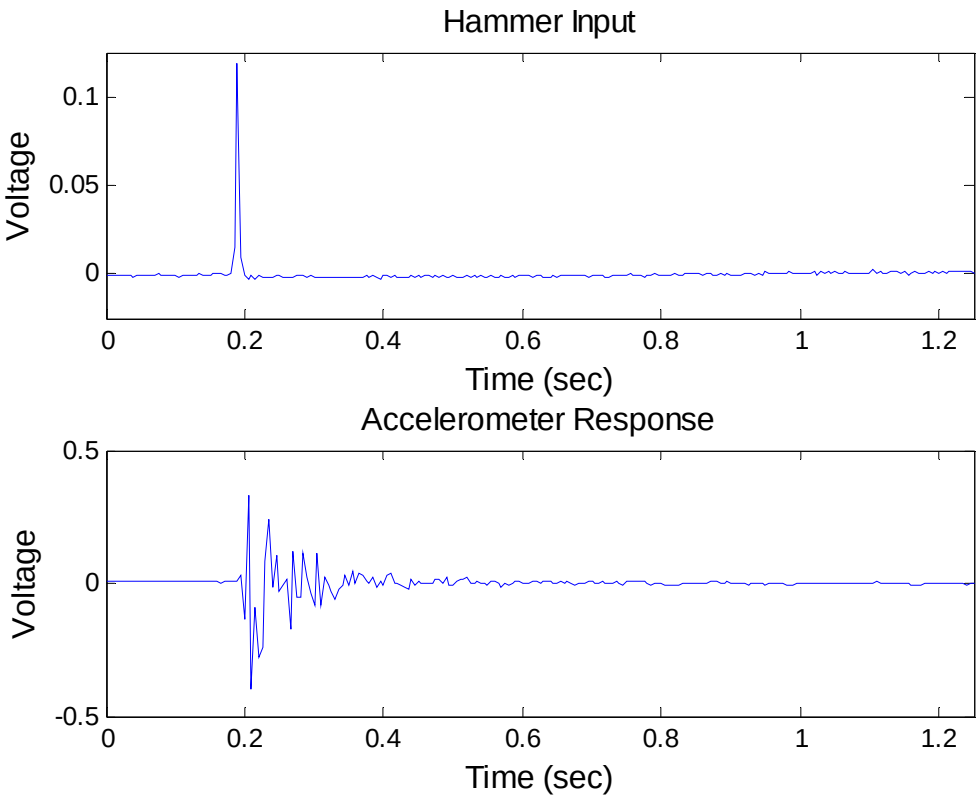
After performing the baseline modal test with a conventional wired system, six WiDAQs were installed in the structure. An installed WiDAQ with its enclosure is shown in Figure 16. Four PCB model 336C accelerometers were connected to each of five WiDAQs, for a total of 20 acceleration measurement channels. The PCB model 086B0 impact sledge hammer was connected to one input channel on the sixth WiDAQ. Specially designed ICP boards were used to condition the measurement data for the AD7924 A/D converter. An additional ZigBee device was used as a network coordinator to control measurement triggering, and to interface with a PC to collect the measured vibration data.

Time synchronization is of particular importance with data acquired for modal analysis. To begin recording acceleration data, the network coordinator broadcasts a start signal to all network devices. Using a single-hop network, the coordinator is in direct communication with each WiDAQ, and each device begins recording data simultaneously.

Each WiDAQ recorded a 20-second time record at a sampling frequency of 200 Hz for each of the four channels, utilizing local flash memory to store the recorded data. A total of eight impacts were given during this time record period. At the end of the time record, each WiDAQ transmitted their data in turn to the coordinator, which passed the data to a PC through the serial

port. Figure 17 shows a segment of the input time history and the subsequent time response from one of the accelerometers recorded by WiDAQ.

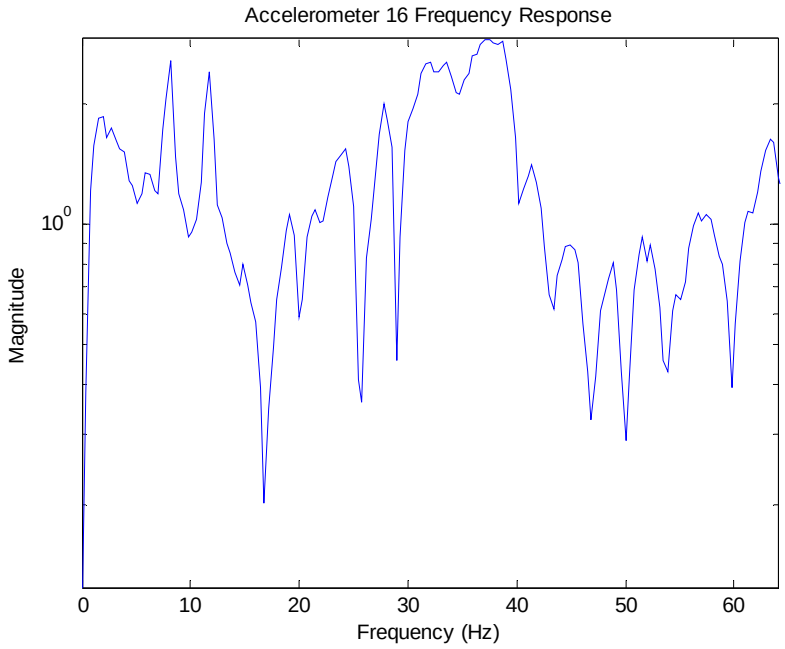
Figure 17. Time history excerpts recorded by a WiDAQ during the 20-second measurement.



The frequency response function after processing the raw time domain data for the measurement shown in previous figures is shown in Figure 18. The FRF clearly shows resonant peaks near 8 and 12 Hz, roughly corresponding to the first and third vibration modes identified using a traditional modal test.

One disadvantage of the WiDAQ system is that its resolution is limited by a 12-bit A/D converter, compared to the 24-bit resolution of the traditional data acquisition system. As a result, the normally low amplitude response of the bridge is not captured as clearly. The use of a high resolution (16bit) converter would improve the precision, but it would come with higher power consumption. This issue is currently being investigated by the authors.

Figure 18. An FRF estimate of the raw time data measured by WiDAQ



It should be noted that the use of the WiDAQ functionality is not fully integrated with the mobile-agent. However, as shown in the previous testing, it can be envisioned that the mobile-agent could dynamically associate with the network, execute a command and collect data, and provide computational resources to process the data for the sensor node, while travelling through the network. For instance, the data processing of the previous example (calculating FRFs) could be done on the PC of the mobile-agent while it moves to the next sensor node and collects data.

As shown in the results, we successfully demonstrated that our sensor node is capable of measuring the low-frequency data, those typically used in modal analysis. The A/D chip used in the WiDAQ can be configured to interact with many different sensors, making our sensor node a versatile platform that could be used in numerous sensing applications.

9. Summary and Conclusions

In this paper, the current research in developing a mobile-agent based sensing network paradigm is presented. This paradigm is designed to overcome the limitation of the existing sensing

network for various sensing network applications. In particular, a series of the wireless sensor nodes designed for inclusion in a mobile-host wireless sensor network has been described for structural health monitoring applications. The wireless impedance device, which capitalizes on the well-established impedance-based structural health monitoring technique, was developed to monitor the conditions of a structure. The sensor node requires very low-power and is capable of being wirelessly triggered by a mobile-agent for use in the proposed mobile-host based wireless sensing network. The mobile-agent is equipped with the capability to dynamically associate with any local network to perform intended operations. Furthermore, the node is capable of collecting low-frequency vibrational data for various applications. Wireless energy transmission offers an alternative method for powering wireless sensor nodes in SHM or other engineering applications and demonstrated the effectiveness in this paper. The advantage of RF energy transmission is that it augments or removes the need to have a conventional power source embedded within the structure with each sensor node. The performance of these devices is first verified in the laboratory. Subsequent field tests demonstrate that these sensor nodes can efficiently monitor several mechanical response parameters suitable for rapid assessment of structural conditions.

10 Acknowledgements

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Turquoise Energy Ltd. News #93

covering October 2015 (posted November 8th)
Victoria BC
by Craig Carmichael

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Month In Brief (Project Summaries)
- Pulse Width Modulation for motor controllers - Atmospheric Energy - High vacuum pump for evacuated tube radiators for thermoelectric cooling? - NiMH Battery connection problems.

In Passing (Miscellaneous topics, editorial comments & opinionated rants)
- Legislation must be Ratified by the People - Energy Density: Gasoline vs batteries? - Importance of Location for Industrial Activities - Negative interest rates - Another High Frequency Trading Scam - Itchy chocolate - Book Barn Mini Library - Supercorder at Band & more interest in it

- In Depth Project Reports -

Electric Transport - Electric Hubcap Motor Systems
* Unipolar Motor Controller: pulse speed control input to improve performance.

Other "Green" Electric Equipment Projects
* Peltier Module/Thermoelectric Cooler ('TEC') Experiments: supply voltage versus attained cooling - 15 amp Peltier module - better ice tray - internal fan - evacuated tube heat radiator - DC to DC converter

Electricity Generation
* Atmospheric Ions - free energy from the electrical charge of thin air?
* Sigh, month ends with far more questions than answers.

Electricity Storage - Turquoise Battery Project (NiMn, NiNi), etc.
* Lead? Lead? The acid battery element has potential uses for alkaline or salt batteries, where it just might have 'forever' cycle life.
* Lead-acid battery charging & cycle life extension: pulse charging.

No Project Reports on: Variable Torque Converter Transmission, CNC gardening/farming machine, Electric Weel, battery making, aquaponics**,** Magnet motor project.

October in Brief

A lot of October just seemed to slide by without getting a whole lot, or even anything, done on sustainable energy projects. There were many things needing doing around the house. I went to Comox on the last weekend for my mother's 90th birthday party, and then my brother who had come from Toronto stayed with me for a couple of days, leaving on Halloween morning. I caught his cold, with headache most days. That delayed this newsletter as well as projects. Somehow, however, I have touched on quite a number of diverse topics in "In Passing".

Early in the month I designed a circuit and PC board for a pulse width modulator (PWM) for the motor controller. It would be an external input to the motor controller board, the PWM at 7Hz replacing the usual analog speed control potentiometer.

According to things I've heard, at least with a unipolar motor controller, one gets better energy usage with low rate pulses to get the desired power level than with analog modulation, with the reason evidently being to saturate the magnetic cores of the coils (or at least to run always at full power), then letting the force drop to zero, repeating in succession. This may not entirely make sense in a traditional design sense, but according to many it works. But after completing my design and layout there was a

long pause.



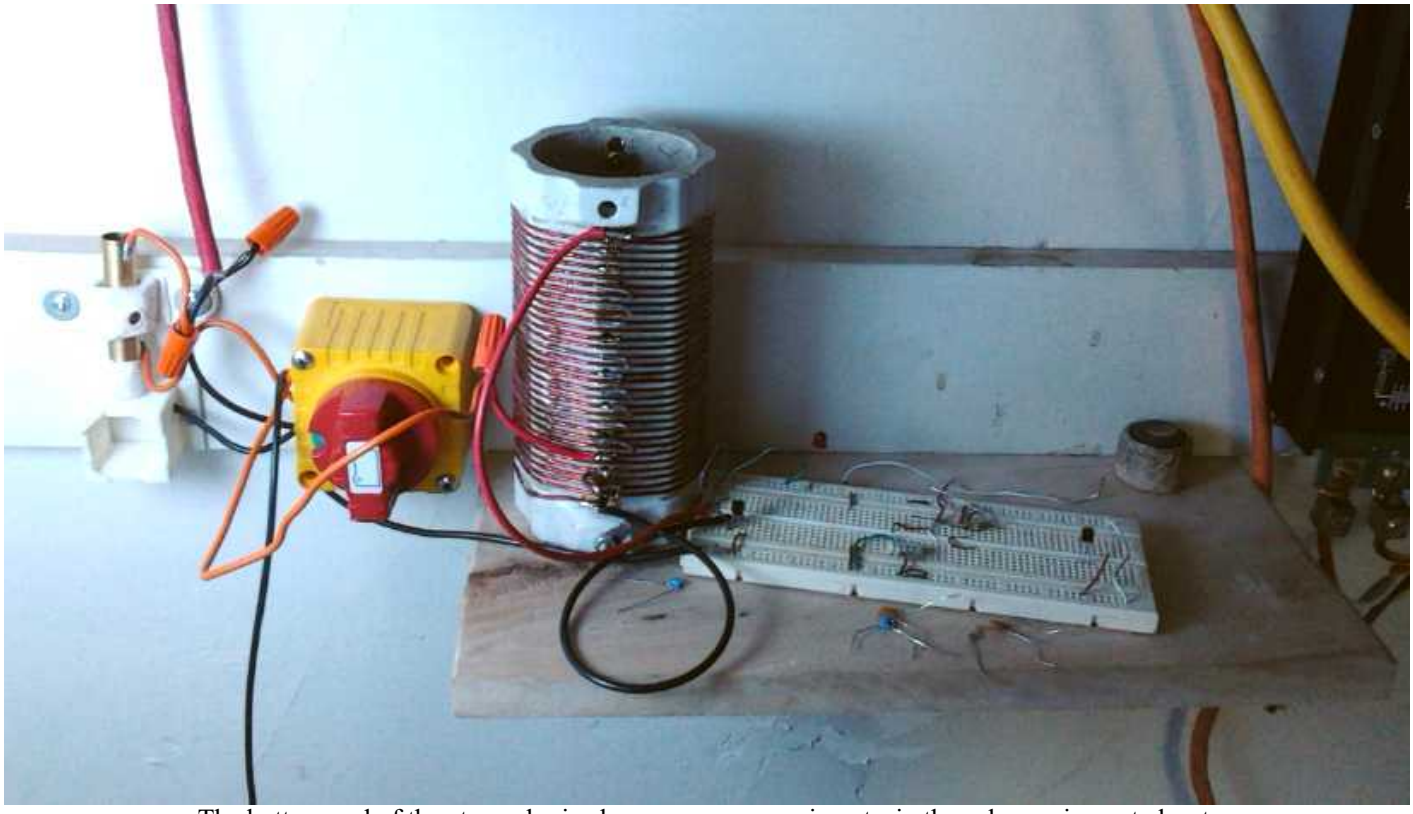
I wanted at least to start in on atmospheric energy experiments. I made an antenna for it and installed it at the peak of the roof by the 16th. I ran a shielded cable down the same route as the solar panel cables into the solar equipment closet.

In all the searching through youtube for atmospheric energy info, inevitably some enticing videos about other forms of 'free energy' including magnet motors were in the 'suggestions'. One person, " (Something) Stators", had a bicycle wheel rotor test setup with a well shielded magnet on his stator, which he said offered the rotor magnets little resistance as they approached but gave them a big push as they passed by. It was similar to an idea of mine but he had done a working construction with the bicycle wheel. I too think the shielding and concentration of flux is the key - or at least one key. I started coming up with new designs in my head again.

However, only once did he seem to have a design that actually kept turning. Even then, after a bit his cat, tentatively pawing at it a few times, dragged it to a stop, showing (along with the pretty low running speed) how little actual torque there was. As a generator it wouldn't put much out. Yildiz, with his 2000 magnet motor, seemed to get a measured maximum of 200 watts AFAIK (tho I remember hearing 400 somewhere). Given the time quite a few people have put into getting meager results or failures, I think I'll stick with the atmospheric energy as the better bet!

Moray got up to 50 kilowatts. Five kilowatts would of course be fantastic. (If I ever get my bitcoin miners running properly, I could then run them and they'd also heat the house for free!) One KW would still be great. A hundred watts would require installing a goodly number of antennae and units to make a real dent in the hydro bill. Ten watts might be practical for limited off-grid applications. Of course, a unit generating 24/7 would have far more impact than solar panels of the same rating that run a few hours a day and only when it's sunny and there are no chemtrails. But reading more on Moray at the start of November, I discovered that his later units actually needed no antenna or ground, and worked for example inside a submarine. That would indicate he was surely harvesting "lambda rays" rather than atmospheric ions - at least with his later units... but weren't they just derived from the earlier ones? Hmm, hmm!

Again I got sidetracked into other things. It was the end of the month before I tried the oscillator(?) circuit of 'Tesla Cult's youtube videos of 2012. It didn't seem to work for me. Furthermore, the oscilloscope disclosed only a 60 cycle hum at about .4v peak to peak and virtually no DC component. There was none of the high frequency noise components noted by Moray and seen on Tesla Cult's oscilloscope. Perhaps insulating the antenna with high dielectric constant material as suggested by someone else is a mistake. Maybe good, clean metal is better. Gold plating?



The bottom end of the atmospheric charge energy experiments, in the solar equipment closet.
Cable from antenna with spark gap, antenna grounding switch, shelf with the air core coil/transformer and circuit breadboard.
(At the far right is solar PV wires and equipment.)

Someone long involved with refrigeration came over (from across town in an electric handicapped scooter) and we talked on the subject. He mentioned having a high vacuum pump. I thought it might be used to make the evacuated tube radiators I've been wanting to make but have been unable to get a sufficient vacuum in by the steaming method. He pointed out that the water in the pipe would turn to steam and condense in his pump. Somehow I quickly thought of freezing the water and pipe in the freezer and then evacuating it. Then the water (ice) would stay in the pipe as desired. He thought that could work. Now I must talk with him again soon and get moving on it, as there's no guarantee at his age and health he'll be around and mobile when it's convenient for me to get around to it. Maybe I can learn some more, and perhaps buy the pump?

In August and September I had been smelling a "burnt plastic" smell at times when driving the Mazda RX7 EV - often when I needed the most power, climbing hills. Finally in September the culprit was located: a loose connection nut on the soldered nickel-metal hydride battery in the back of the car. (this battery: see some TE News issue of maybe 2013.) With the loose connection, the bolt with the wire had been getting hot, and pressing against the side of the neighboring lead-acid battery it was melting its way through the side. Luckily it hadn't got all the way through the wall yet, and just as luckily the car hadn't let me down going up a hill. I tightened the nut and put a piece of wood between the two batteries to keep them apart.

The smell stopped, but the problems weren't over with. I connected the NiMH battery to one of the voltmeters on the dash and found that it seemed to now be the weakest of all the NiMH batteries, with the voltage dropping lower when power was needed and the charge being depleted sooner than any of the others. Although it was the first soldered NiMH battery I had installed, it had been with all new cells. I wasn't driving more than about 4 miles, by which time it obviously needed recharging. Finally it occurred to me that it behaving was as if it was 50 amp-hours instead of 100. And it was made in two 50 amp-hour boxes.

I pulled it out, brought it inside, and started to disassemble it. On the bolt that had the loose wire there was a nut with melted plastic on it facing a washer with melted plastic on it, and the wire in between from the lower box to the upper had some grit on it. Although the nuts had been tightened, these things had conspired to cause the lower box to be unconnected. I cleaned it up. While it was out I opened the lids, and found that two of five wires in one box had come unsoldered and so two sets of 10 amp-hours weren't making connection. At first I thought they must have melted off, but close

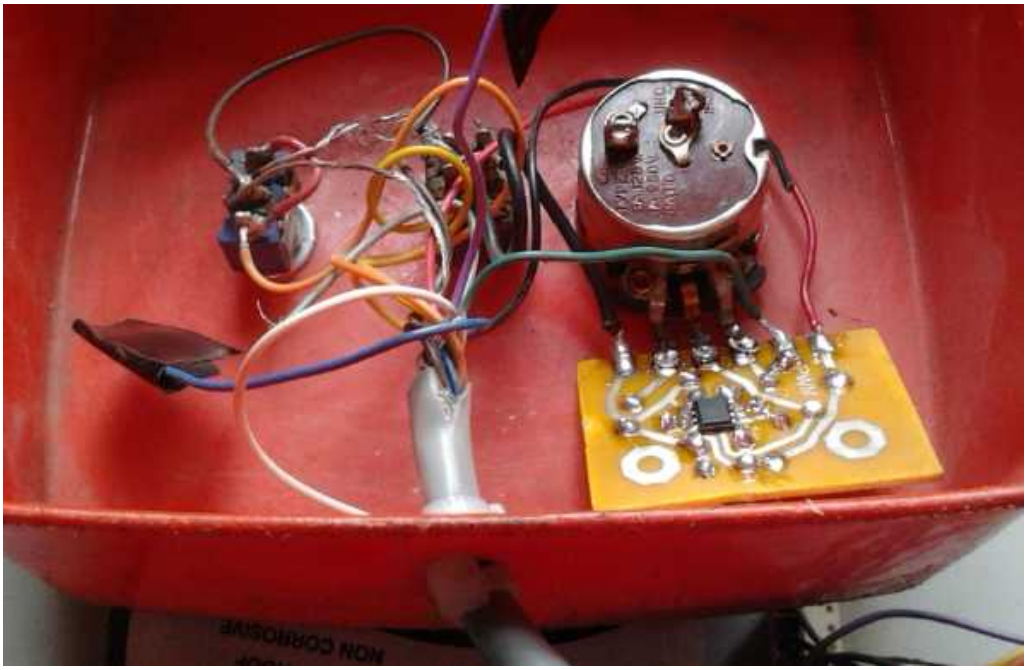
examination showed untinned copper surface - the original solder joint had been poor.

Also in October, the owner of the one NiMH D-cell car battery I had made and sold (somewhat ironically for his Honda Insight hybrid) brought it in because after 3-1/2 years it wasn't working well. (battery covered in some TE News issue from 2012 or 2011.) I had asked him a couple of years ago to bring it in as I had discovered the safety concern with just the thin plastic sleeve casings on the cells, and had had some packs burn up on me after being badly overcharged. And I had used the stiff copper "buss bars" to connect the cells together, which I gradually found out gradually come loose with vehicle road vibrations. I wrapped the cells in masking tape for thermal protection, and replaced the bars with AWG#16 flexible stranded wires, formed into little arcs to allow for more flexing. There were 3 or 4 copper bar connections that had come loose, definitely explaining the reduced performance, and a couple more that might have gone soon. One of the terminal posts was also quite loose, and I pointed out that the clamping nut had to be on tight to ensure good connection. I tested all 30 cells with a voltmeter while I had them apart, and they were all holding their voltage.

As I write about the loose bolt/post, a better system comes to mind: instead of clamping the connection bar between the bolt head and the case with a nut on the *outside*, clamp the internal connections between the bolt head and a nut *inside* the case. That (hopefully) can't be loosened from the outside. There would still be a nut on the outside to hold the bolt in place, but it wouldn't affect the connections and pehaps cause the case to get hot if it came loose.

On the 26th I finally got back to the PWM for the motor controller and I got the board made, working (not without a couple of little problems along the way), and installed in the test controller. Then it sat a while again. On November 3rd I decided as it was made I'd better at least try it out for this newsletter, so I hooked it all up and ran a few tests. It seemed to run about the same except for the definite pulsing action. As the power supply was balking at the currents, I powered it off the handiest thing: the 14.4 volt, 65 amp-hour Honda hybrid battery. So I was running it at half the voltage and the same current, and getting similar results. That seemed agreeable. I bypassed part of the shunt resistor (for a lower shunt resistance) and got higher currents in both directions, which provided a higher but still very low top RPM of about 225. The DC clamp-on ampmeter attached to the oscilloscope seemed to indicate that the energy return current spikes were higher voltage than the supply current spikes. Doubtless that must mean they were a little narrower, but the battery voltage dropped surprisingly little over the course of the testing, indicating pretty low energy use. The peaks were about 14 amps used for the 225 RPM, delivered as short spikes of 150 to 300 amps with return spikes of around 250 to over 400 amps. The energy return coil still got hot, and obviously the average supply current has to be a lot higher to get any real power out of the motor.





Pulse Width Modulator Board on pot, and installed in hand-held control (SOIC 555 timer chip on bottom)
Aside from the direct-soldered potentiometer it has 3 leeds coming off it, just like the analog pot alone:
Ground, Power (12V), and PWM out (0 or 4 volts with a resistive divider).
(Circuit drawings/files in detailed project report.)

In Passing

(Miscellaneous topics, editorial comments & opinionated rants)

Legislation must be Ratified by the People

As we enter the internet age, new forms of communication and democracy, such as direct voting via

the web are becoming feasible for the first time, and at the same time there is a global awakening in social consciousness.

Today's governments have mostly turned their backs on the real needs of their citizens and social progress in favor of special interest groups who broker their power for profit. When the politico-economic power base is shattered as it doubtless will soon be, from semi-chaos we will have the chance to reorganize from the local level up in sustainable ways.

On the one hand, there is a need for elected government made up of experienced, concerned citizens who have spent more time than most studying the problems of society and devising solutions. On the other hand, centralized power seems to increasingly attract virtually the opposite type of people: the corrupt, the greedy, the power hungry, the manipulators - insincere liars and sociopaths, devoid of progressive ideas and ideals of social sustainability. And these shut the honest and good-seeking citizens out of the fierce competition for political and economic power. We need leaders, not rulers.

Some aspects of power need to be widespread, so that those elected will have no opportunity to run roughshod over the rest, and holding office won't attract those types. This has become possible. People today know a lot more than those of previous generations, and can learn more about what's going on more quickly. They will want to know first why their social and political institutions, unexpectedly to most, suddenly fell apart, and how it was that so many were so asleep until it happened. And they will want a more direct say in running the new ones to ensure that autocratic decisions aren't imposed on them by those from whom the police and the military take their orders.

Of course the citizens need the right to hold referendums on any chosen issue. But it now seems to me that a possible solution, a balance to the centralized power, is that any bill passed by a legislature would have to be ratified directly by the citizens, doubtless after time for due consideration and discussion. This seems like the best way to eliminate odious and perhaps deceitful legislation turning peoples' rights over to the state or to special interest groups, and increasingly micro-managing everyones' affairs with thousands of laws and bylaws. Such bills would probably fail at the public scrutiny level, and the leaders would realize it would, therefore they're unlikely to be pressed forward, and the types of people who would press them will be the ones who won't bother running for office. Both of these polling functions would be implemented via the internet in some form.

Gasoline: high energy density?

I happened to look up aluminum ion batteries on Wikipedia to refresh my memory, and saw it said that even tho they were over a kilowatt-hour per kilogram, petroleum was much higher energy density. So I looked that up, converted joules to kilowatt-hours, and got 12.33 KWH/Kg for gasoline. At a glance, this is twelve times better. But one must consider that the automotive gasoline engine is seldom over 20% efficient, and add to that the inefficiencies of the drivetrain components like the 30%-40% loss in a typical transmission (standard-automatic). Call it 50% loss overall. The overall efficiency of the typical car drive is then around 10%. So the 12.33 effectively becomes 1.23 KWH/Kg. The rest of the energy is wasted as heat. An electric drive can be made much closer to 100% efficient (up to the rubber tires and their road friction being similar), and of course a major goal of my projects has been to improve efficiency, eliminating the wasteful transmission one way or another and achieving the highest drive motor and controller efficiency.

Of course no one is actually using aluminum ion batteries at this point, and typical automotive lithium batteries are probably under 200 WH/Kg at best. (Don't quote me on that!) Lead-acids are 40 WH/Kg or less. Furthermore, as the gasoline is burned its weight vanishes, while the batteries remain as dead weight until recharged.

Still, there are promising new battery chemistries out there such aluminum ion and several enabled by new DES electrolytes, and as battery energy density increases over 100 or 200 watt-hours per kilogram, the weight of the batteries as a percentage of total vehicle weight starts to shrink and battery weight starts to matter less than battery cost and cycle life. Add to that a reduction in required battery capacity through higher efficiency, the ongoing cost of gasoline and the likelihood that it won't always be available, Fast charging and new public charging stations popping up everywhere, and the electric car starts becoming the obvious economic as well as ecological choice.

Importance of Location for Industrial Activities

I read an article in the *Financial Times* [http://www.ft.com/] about industrialization creating less and less in the way of jobs and wealth with each new industrializing country. I found one of the comments

someone posted below the article to be of particular relevance to the work I've been doing. The writer says that industry even in "industrialized" nations is concentrated in a small number of "clusters". He went on:

"In a former life I have worked as an industrial consultant and by observing it became clear companies inside the industrial cluster have a competitive advantage in that they have access to a dense local network of specialized suppliers and know-how that often requires proximity to work well and is absent outside the cluster. In other words, network effects are at play. Furthermore, the presence of a sophisticated manufacturing base allows new types of technologies and niche suppliers to develop, often requiring proximity to customers - e.g. machine vision systems for automated quality control. These then further strengthen the competitive advantage of that cluster. The more technology advances, the stronger these network effects become thereby further cementing the competitive advantage of the cluster versus the world around it. 15 years ago, when visiting competing companies in the same sector, it was obvious the ones in Germany/Italy were way ahead of those in France, Spain as the latter lacked plug-in into a strong local eco-system. I suspect since then the divergence has only widened.

"This is also why Australia's doesn't manage to industrialize and despite its highly educated population, one should always be short the Australian dollar outside a commodity boom. This is also why Greece will always run a deficit when in a currency union with Germany and the EZ crisis is perpetual: if Greece were somehow geographically moved in between Germany and Switzerland, its problems would quickly disappear.

"This is also why everybody now wants to move to Germany as the manufacturing base won't come their way. They have a point.."

I have struggled from the beginning of the "car hybridization" projects with the fact that nobody around here seemed to know anything or have any parts when one gets into the nitty-gritty of various mechanical and technical areas. If I was located in a "cluster" area where cars were manufactured, I'm sure I'd have had a much easier time with a lot of things.

But I think as the internet has further developed, some of the handicaps are being removed, and that this trend will continue into the future. More information is more accessible, and it's getting easier to access parts and services. Progress in manufacturing automation has also progressed. With various computer controlled devices, for example abrasive waterjet cutting of steel and 3D printing, many things that used to require expensive design and setup or painstaking fabrication with lathes, welders and milling machines, can now be designed on a computer at home and done either there or at a local facility by automatic machines. Low cost services are available for making printed circuit boards in China simply by e-mailing the design, with the finished boards being thrown in the mail - no need for proximity there! - and there are now automated PCB assembly facilities even in Victoria BC. And prototype boards can be done in a day at home as I've been doing, with laser printer toner transfer techniques.

As communication and distribution improve, more and more we can have self-sustaining local communities.

Negative interest rates

Today bank deposits earn almost no interest. With inflation, it's effectively negative interest rates - the buying power of your savings shrinks. For many currency is safer at home in cash. (*IF it can be very well hidden, preferably divided into small packets, and that doesn't mean somewhere in your bedroom. A hidden safe, well bolted down, might be invaluable - they start at under 100$.*) Or maybe some in a non-bank account such as paypal. In some European countries actual negative interest rates, albeit small ones so far such as -.1 percent, have been applied to bank accounts. It's hardly a way to watch your savings compound! In recent weeks there have been mutterings from the US "Federal Reserve" banking corporation about instituting "NIRP" (negative interest rate policy) in the USA. Such a "policy" hardly seems designed to attract deposits. Indeed, it has been noted that people in affected countries have been gradually withdrawing their money. In order to combat this, rather than making banking more attractive, there are plans, or at least ideas, afoot to ban cash in order to force people to keep their money in the banks - to force them to lend the banks their money regardless of negative rewards and risk - and by the way allow the government to spy on and review each and every financial transaction of every person - rather than keep it more safely (less dangerously?) themselves in cash.

I tend to dismiss this problem because I think the whole ponzy scheme global financial system will

crash before such a system could ever be implemented. One can never say what surprise tricks might be used to "kick the can down the road" a little longer, but personally I expect the can to grow a handle well within a year. Then it will be a bucket, and the financial system will suddenly "kick the bucket" on its next kick. NIRP or "bail-ins" (the everywhere-threatened direct theft from deposits by government and banks) might do it, or the bond bubble implosion, or derivatives dominos, or running out of gold or silver, or there might be some unexpected cause. Expect chaos to spread quickly when that happens and last for years (2 or 3?) until the survivors figure out how to get vital trade and food supplies moving again.

In the meantime, as long as negative interest rates are fairly and consistently applied to all, I am for them! In fact, I look forward eagerly to getting interest payments from the banks based on my mortgage and credit card debts instead of having to pay out on them!

Another High Frequency Trading Scam

Last February the CAVirtex.com bitcoin exchange in Calgary Alberta announced it was shutting down, citing "a security problem". It was a complete surprise to all. It asked all account holders to withdraw their bitcoins and Canadian dollars amounts within the next month and close their accounts, and trading ceased in March. I withdrew "everything", but as it wasn't possible to get everything exact, I had left over one penny and something like .00012 bitcoins - trivia.

The next surprise was two or three weeks later, when CAVirtex.com re-opened under new management. It didn't look like anything had changed a whit. My account was still there with the small change.

But I had already noticed in the weeks leading up to the closing that suddenly most of the trades were being front-run by some high-speed computing algorithm. This has become common on Wall Street in the stock markets (and as usual there's no investigation, and no one is ever charged or goes to jail), but is a huge cash cow in the bitcoin market on CAVirtex.

The price of bitcoin having risen recently, I decided to sell some to pay expenses. Normally, when you go to buy bitcoin on an exchange you can look at the trading page and either offer the amount of the lowest sell offer and buy immediately, or you can make a lower offer and wait for someone who will sell at your price.

Now (buying) if the lowest offer to sell bitcoin was for 500 $/BTC, you can offer that price to buy immediately. But when you do, your purchase instead goes through for 499.99 $/BTC. Afterward, the bitcoins for sale at 500$ are still all there: the seller has sold nothing. Instead, when you hit the last key or mouse click to buy, somehow before your offer hits the exchange, it's intercepted, and instantly someone else puts in a sales offer for your exact amount of bitcoins at 499.99$. That 499.99$ offer takes precedence over the 500$ and immediately goes through, so fast that it never appears on anyones' computer displays in the 'bitcoins offered', only in the 'completed transactions' section. Unless he looks down there, the only thing the offerer for 500$ sees is that none of his bitcoin has sold yet.

The same thing happens with selling bitcoin: if the highest offer to buy is 470 $/BTC and you offer to sell for that much, your trade goes through instead for 470.01$, and the would-be buyer is left high and dry. Instead, the front-runner, who just sold bitcoin at 499.99$ moments ago, now buys it back for 470.01$ and pockets the 29.98$ (less the exchange's transaction fee of .75 or .5%). If the exchange trades 200 BTC a day and the spread is 30$, and if 90% of the trades are front-run, the scammers are making 5400 $/day. This money comes off the backs of everyone trying to buy and sell bitcoins on the CAVirtex exchange, who can't make their trades go through except by buying and selling at the asked and offered prices, always getting the least "bang for the buck" with most of the trades going through the hands of the scammers who pocket the difference.

This is just now appearing also on the Quadriga.com bitcoin exchange in Vancouver: I just lost a sale for .75 BTC, with a "sell" offer for 1.00 bitcoins being posted as I watched and asking a dollar lower than me, which proved to be exactly the amount of an offer to buy 1.00 bitcoins just before it appeared. It was visible on the listing for just a few seconds before the trade went through. Then I looked at 'recent trades' and saw that they all had been for a dollar less than my price. I don't remember that happening before.

It may be that the scammers have acquired physical intercepts into the exchanges' internet lines, so that all the communication goes through their equipment first and their computers can pick and choose with every transaction. This would be a variant of what's been done to the New York stock exchanges for

high frequency trading. It may even be that it was the scammers who re-opened the CAVirtex exchange after it was shut down. They could certainly afford to buy it with their illicit profits, and they certainly have every incentive to keep their rigged game running! And then they even keep the transaction fees.

Perhaps more needs to be done through "local bitcoins" - private buying and selling of bitcoins not through on-line exchanges.

Itchy Chocolate

I used to get unbearably itchy in my 20s, and I scratched so much I now have various nasty moles and things on my back and chest. When I was 29 I finally discovered it was from eating chocolate, which I was eating a lot of. I quit eating chocolate and gained much relief. A lot of things give me migraines, including most processed or non-fresh milk products including milk chocolate. But after over 30 years, I forgot the other reason I don't eat chocolate, and I bought a big dark chocolate bar at a grocery - maybe dark chocolate wouldn't didn't give headaches like milk chocolate? After having too much for 2 or 3 days, I was unbearably itchy the next night. I thought maybe pollen, which I'm allergic to, had somehow got on my bedsheets. As I washed them the next morning I remembered about itching from chocolate. I related this to a friend and gave him the rest of the chocolate bar. The next day he said he had had several itchy sessions at night for no apparent reason. I thought it was just my own allergy. Is this a common reaction? After a few days of itchy chest, I also got a zit there, also doubtless from the chocolate (not from the itching per se).

Book Barn Mini Library



In the middle of the month I finally finished a project inspired by a "resilient streets" meeting in the spring and made from a boulevard giveaway cabinet I put a cor.o.plast "roof" on: a very local place for

people to exchange books. A number of books have come and gone. I think more 'duds' have come or remain, and more interesting ones have gone. The books mostly seem to have come in three batches: the ones I initially set out, a batch someone else brought, and a batch of cookbooks from another person. At one point, some 'librarian' set them all up nicely. Someone kicked in one door. I feared it might soon be completely vandalized and wondered if it was silly even attempting it, but it hasn't happened yet. Lately there's been a big plastic bag over it to keep the heavy rain out.

I found a video of the original "Resilient Streets" book boxes, and they were nicer, mounting on posts and with glass (lexan?) doors that open, to keep the rain out.

Supercorder at Band & more interest in it

Having been asked to leave the "Intermediate" band because my Supercorder "doesn't sound the same as a flute", in the last week of October I re-joined the "Junior" band, where the conductor, and a few players who said something had seemed to be missing without my sound, seemed more than happy to have me back. As there were no oboes I'll mostly play oboe parts - and sometimes flute where the oboe part has nothing, tho there are six flutes this year.

There was further interest in my instruments in an e-mail. Some else wanting to experiment with improving recorders asked where I had got my information. That was here and there, and I realized that if I wrote up some "tips and principles" of recorder and supercorder design, it might save people a lot of time and grief. Doing so further contributed to delay in writing this newsletter. And I think expanding on the subject, showing some of my jigs and techniques, might also be more than helpful to potential makers, so I may take some more time out to do so. There are lots of guitar and violin makers and doubtless lots of books and plans for them, but there's really not much info for an aspiring woodwind maker to go on.

Newsletters Index/Highlights: http://www.TurquoiseEnergy.com/news/index.html

Construction Manuals and information:
- Electric Hubcap Family Motors - Turquoise Motor Controllers
- Preliminary Ni-Mn, Ni-Ni Battery Making book

Products Catalog

(Will accept BITCOIN digital currency)

...all at: http://www.TurquoiseEnergy.com/ (orders: e-mail craig@saers.com)

Daily Log

(time accounting, mainly for CRA - SR & ED assessment purposes)

Oct 1-4: More research on aerial energy devices - Read Tesla's famous patent on the subject. (Also watched a technical video about Bedini motor.) But mostly editing newsletter.
5: Picked up NiMH Honda Insight battery sticks & cleared through customs.
6: Researching on aerial energy (a couple of good technical videos - Ion Power Group, more).
7: Started laying out a PCB for a 555 timer based PWM control to attempt some additional pulse strategies with the unipolar motor controller.
8: Finished PCB layout
9: More video 'atmospheric energy' studies.> (Inevitably some stuff on magnet motors too.)
10: Still more video 'atmospheric energy' studies.
11: -
12: ditto to 9th and 10th. I also spent quite a while writing an e-mail to MicroMetals[.com] looking for advice on coil core types for the motor controller.
13: Bought heavy "battery" switch for grounding atmospheric energy receiver antenna. (safety for electronic circuits and for people, esp. me.)
14: Bought a "gutter guard" aluminum plate to use for plate antenna.
15: Constructed atmospheric energy receiver antenna assembly and mounted it up on peak of roof.

(~40' elevation above ground)
16: Ran cable from antenna to solar panel/12 VDC equipment closet.
17: Major cleanup of the closet.
18: Formed a ceramic insulator set for the spark gap pieces.
19: Fired insulator set in kiln, mounted it in wiring closet.
20: Finished up wiring spark gap and grounding switch, added a small shelf to place circuit breadboard on for trying things out.
21: Wired up coil, connected it to antenna, and tried a couple of things. (No notable results)
24-25: family
26: Made PCB of PWM control
27: Drilled holes in PCB
28: Mounted components & tested & troubleshooted(?) PWM control, mounted in controls box.
29-30: family
Nov 1: Atmospheric energy experiments.
2: (bad cold)
3: Testing motor with PWM controller.
4: cold
5: cold
6: cold
7: newsletter

Electric Hubcap Motor Systems - Electric Transport

Unipolar Motor Controller

I decided to try pulsing the drive at a low frequency, just a few pulses per second, like maybe 6 to 8. This idea goes back to my earliest motor controllers... like the one that actually moved the car, however feebly, with direct drive on the wheel in October 2008. This feat was never repeated in spite of improving the motors. A couple of times I had heard Toyota hybrids make the same sort of pulsing sound as they started moving on electric power.

By repeatedly giving the transistors a brief rest the current, and hence torque, can be permitted to go higher when they're on without overheating them. I also suspect it's the way to get the best performance out of an "active generator", where the motor controller acts like a "regenerative braking" circuit and dumps power 'back' into the 'supply'.

For the PWM generator I made a simple 555 timer based pulse width modulation circuit to feed 7.8Hz PWM to the controller in place of the simple analog potentiometer. That's the Schumann resonance frequency, for want of any particular reason for any particular frequency. (Any RF emitted would travel around the world in all directions and back to the motor in that length of time, FWIW.)

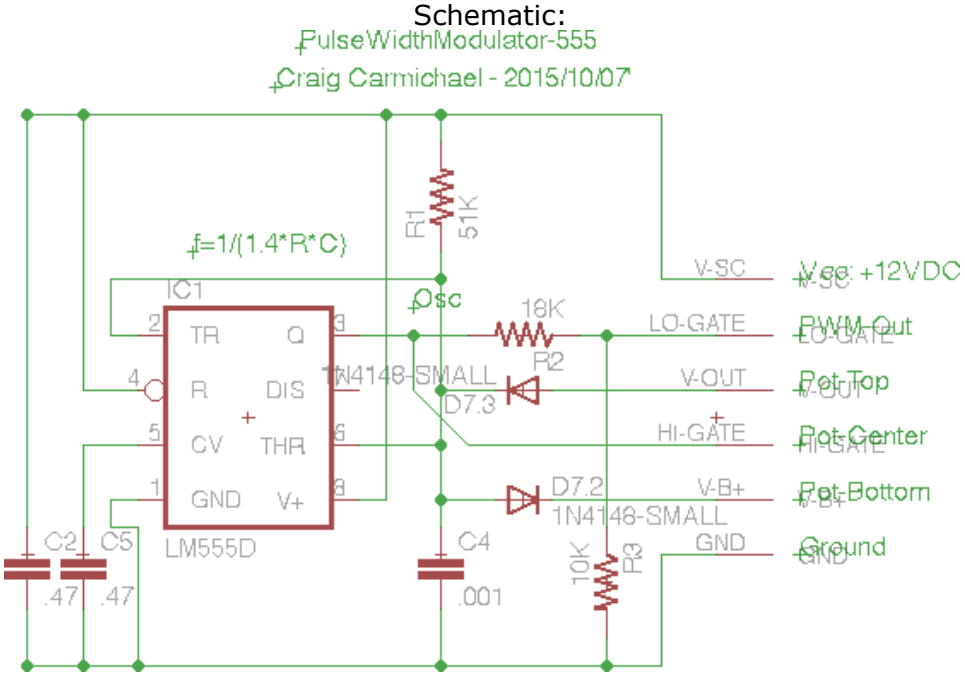
I remembered doing such a PWM generator when I had first started in on doing motor controllers, and I looked for it in my EAGLE PCB files. I couldn't find it. But I knew I had it somewhere! Where was the circuit and the board design? At length I remembered I had wired up the first controller on a breadboard, so there was no PCB layout. I found the circuit diagram (originally off the web somewhere) in the last undamaged copy of the "early motor controllers" manual - an image of the circuit drawn on paper with pencil and pencil crayons. I had forgotten how primitively I started out on all this!

I did the schematic in EAGLE and the PCB layout on the 7th and 8th. There was one aggravation: I had selected the DIP package of the 555 timer and designed the board. Then I checked my stock and found I had the SO08 surface mount package instead. To change it on the single sided board meant it would mount on the bottom and so all the pins were not just smaller but mirror imaged. So it all had to be rerouted, taking 2 more hours, and it ended up needing a jumper, which it hadn't originally. But at least I shrank the board to 1" x 1.2". I would just solder it onto the back of a rotary potentiometer control to 'mount' it. External connections are +12 volts, Ground, and PwmOut (7.8Hz, 5 volts).

I finally got around to printing the 555 timer based pulse width modulator circuit board on the 22nd. Here are the files.

EAGLE PCB CAD files:
555-PWM.sch - 555-PWM.brd

Ready to print artwork (2 copies) at 600 DPI, with the pads expanded in a 'paint' program (Graphic Converter) to make solid solder points on a single sided PCB:
555-PWM-x2.png
Schematic:



R1 should be omitted entirely. C2 and C5 are just filters - .1µF or whatever is fine for both. R3/(R2+R3) sets the output voltage. The potentiometer and C4 set the frequency. As it says in the schematic, f = 1/(1.4 * R * C). If my 500,000 ohm potentiometer is 1/2 way, that's 250,000 ohms in each direction. That's muddied a bit by the diode drops, but we'll use it. Let's see...

7.8 Hz = 1/(1.4 * 250000 Ω * C4 [in Farads])
1.4 * 250000 * C = 1/7.8 Hz or
C = 1/(7.8 * 1.4 * 250000) or
C = 1/2730000 or
C = .3663 µF.

.4 µF gives 7.1 Hz. So how about four .1 µF capacitors in parallel? (Perhaps I should have allowed for multiple capacitors on the circuit board layout?) We still have the diode drops to consider, and the frequency might skew as the pulse width is changed.

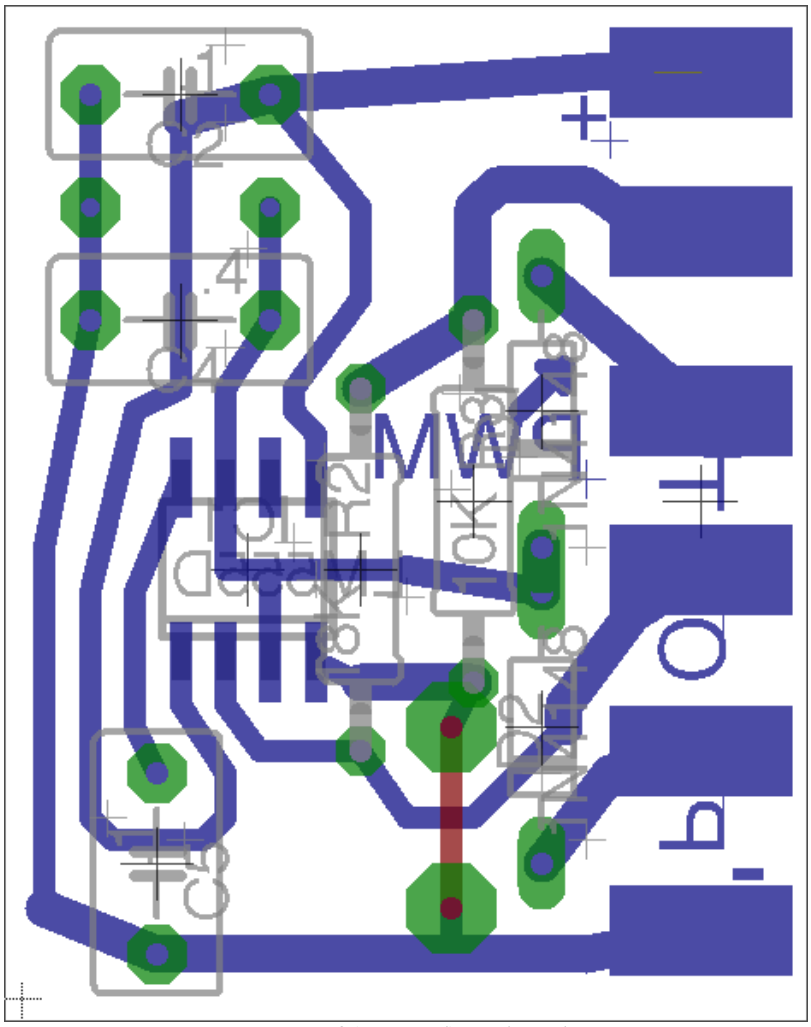
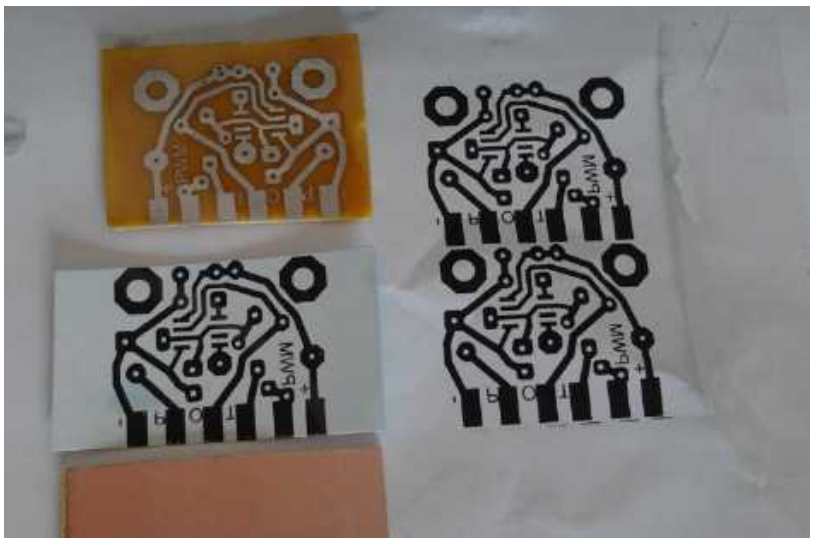


Image of (untested) V2 board



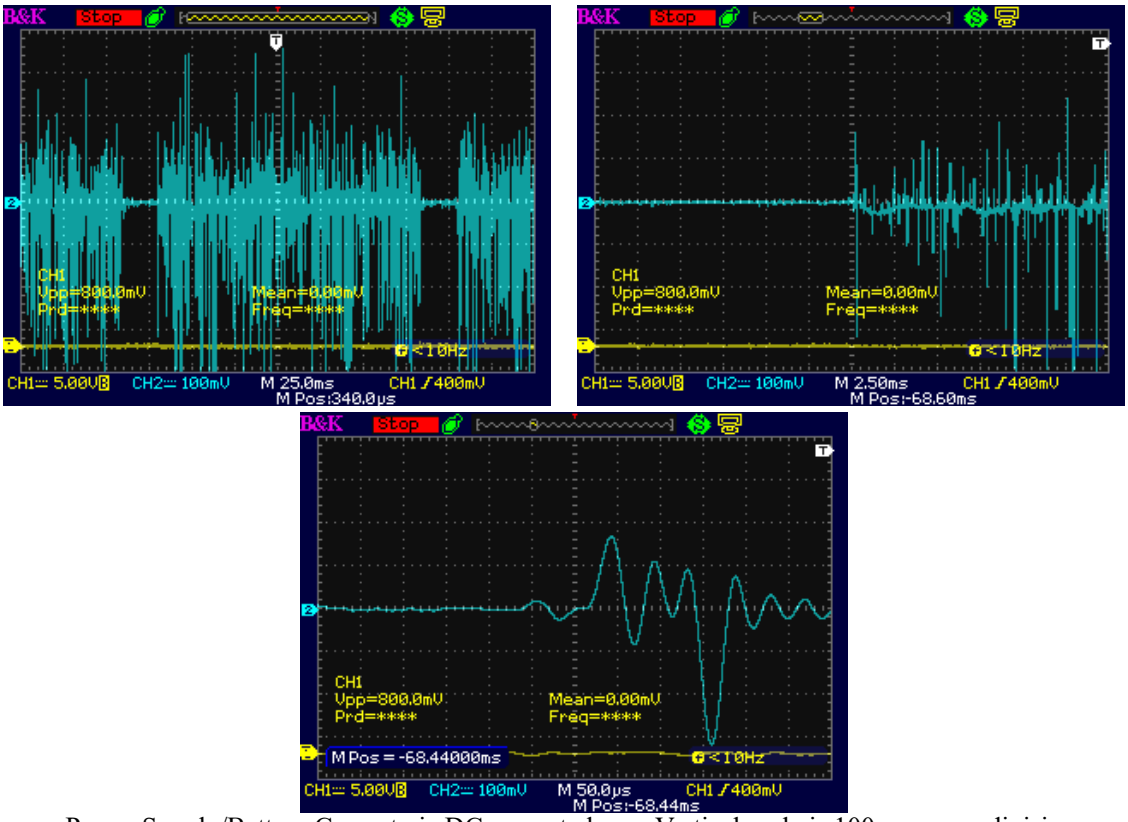
Artwork, first printed on paper (right),
then on toner transfer paper taped to the original piece of paper and run through the printer again (mid),
then laminated onto a copper faced circuit board (lower) with 10+ passes through the laminator,
then the board is etched to leave the desired patterns (top).

I only got around to the project again on the 26th, when I printed and etched the PCB. The next day's puny accomplishment was to drill the holes. On the 28th I finally soldered on the parts and tried it out.

Testing disclosed a mistake in the design, a hangover from copying the schematic from something a little different. "R1" (51K ohms) should simply be omitted. After a couple of hours debugging and changing the design and layout, measurements confirmed that the pulse width varied the frequency

somewhat, from 125mSec to 170mSec, frequency range 5.9Hz to 8Hz. Target was 6 to 8 Hz, so that's great. Pulse width can vary from under 1% to over 99% by adjusting the potentiometer. The potentiometer with the PWM board simply replaces the regular control pot and outputs a duty cycle at about 7Hz at 100% amplitude (or adjusted lower via R2/R3) instead of an analog voltage. It worked for me, and it seems it works for Toyota.

Then my brother from Toronto came to visit for a couple of days and give me his cold. I figured having built the thing that I could at least try it out, and on November 3rd I ran the motor with it. It didn't seem too different from the analog operation except that the on-off pulsing was quite distinct. I put the current meter on it and it said up to 11 amps, same as before. I shortened the shunt by putting the connection in the middle, and it went up to about 15 amps, and a little higher RPM (225). Then I attached the oscilloscope to the current meter so I could really see what was happening. I got the following waveform, shown at 3 time scales. (Upper white figure is time per division.)



Power Supply/Battery Current via DC current clamp: Vertical scale is 100 amps per division.
The 200 amp cutoff is apparently a more approximate spec as made than expected, but it works.
Most 'on' pulses seem to stop at 100 amps, but a few go up to 350 amps, and energy return pulses go down even beyond 400 amps.

Left: the overall 7Hz pattern, with a pulse duty cycle of about 85%(?)
Middle: Beginning of the "on" section expanded 10x
Right: expanded another 50x.

An interesting feature is the high return currents as the coils are switched off, apparently higher current than the input current (but probably of shorter duration). Someone mentioned that the return spikes would be about (or exactly?) twice as large as the original current spikes. Apparently true for current as well as for voltage... but wouldn't that make more power returning than entering? The energy return coil still gets hot rapidly. Now if I had only examined these waveforms with the original analog speed control differences might be evident. Maybe I'll try looking at that later.

Other "Green" Electric Equipment Projects

Peltier Module / Thermoelectric Cooling

With the old 8.5 amp peltier module, it didn't seem to make a big difference how fast the fan was running to carry off the heat. With the new 15 amp one, it definitely cools better with the fan on higher speed. With the internal fan and the larger peltier, the whole fridge is now cooler, mostly 7 or 8 degrees C instead of 10 or higher toward the far end, with the area near the ice tray being around 5 or 6, which it still is. (Lower winter room temperatures sometimes lower that to about 4°.)

That brings us back to my desire for a quiet large evacuated tube radiator, which would have sufficient cooling surfaces to operate without a fan. I talked with someone I knew involved with refrigeration. He said he had a double vacuum pump that would create very high levels of vacuum. But if I had water in the tube, it would evaporate and come out as water inside the pump, doing the pump no good and leaving no water to boil in the pipe. I hadn't been able to make the steam-out of the air work, and now I was disillusioned about my alternative idea of simply sucking out the air.

But I soon had another thought. If one put the pipe with the water in the freezer, the water would freeze. Then the air could be sucked out without sucking out the water. Now all I need is time to put together a pipe with some sort of pinch-off end or other means of sealing it, and go to my friend's shop and see how to best do it. (Does he have a freezer?)

Electricity Generation

Atmospheric Charge Energy

Recap - What and from Where is Atmospheric Charge Energy?

The Earth is a giant dynamo with 200 million amps flowing continuously around it. It might seem only natural that such current provides the known electrical charges in the air, which voltage levels may rise on a clear day by almost +100 volts per meter of altitude. So, if the Earth is neutral in charge, there are more and more electron deficient ions in the air as one ascends. This is what can electrocute linemen touching unconnected power lines from tall, grounded towers, and cause big sparks from cables hung from helicopters. Furthermore, that voltage is an average. There is also a large AC component to it, ebbing and flowing, according to Tesla, and to Moray it sounded through headphones on an unconnected telegraph line like static, pulsating rather like crashing waves, with big peaks followed by decreasing ones until the next big one comes along. On a stormy day, moisture in the air multiplies the effects by orders of magnitude, and the DC charge is often reversed, with negatives at or above the clouds. Lightning is the sudden discharge of the turbulent, highly charged air either to ground or to a "nearby" air space with a different charge. But some of the atmospheric electricity that causes lightning is always present, and can be harvested in controlled, useful ways.

It is well known that a simple circuit of diodes and capacitors can capture the ions that happen across its antenna, producing a small current that can gradually charge a cellphone. (It can also harvest from nearby power lines and radio signals.) A huge antenna such as *Ion Energy Group*'s is required to harvest much power.

But it appears that an oscillating circuit such as those made by TH Moray from 1926 to 1929, probably resonating with natural frequencies of the energies, can multiply the energy, bringing the ions to the antenna and generating vastly greater quantities of useful electricity, apparently at ultrasonic or RF frequencies - LF, MF and maybe HF. The difference is between milliwatts and kilowatts. A good number of testimonials written at the time demonstrates that it did indeed work as stated, leaving no credible possibility of a hoax. [A compilation of them are here: http://svpvril.com/Moray.html -- "Of the great number of learned men who have seen or heard of Moray's work, not one of them has ever been able to disprove his theories, claims and discoveries."]

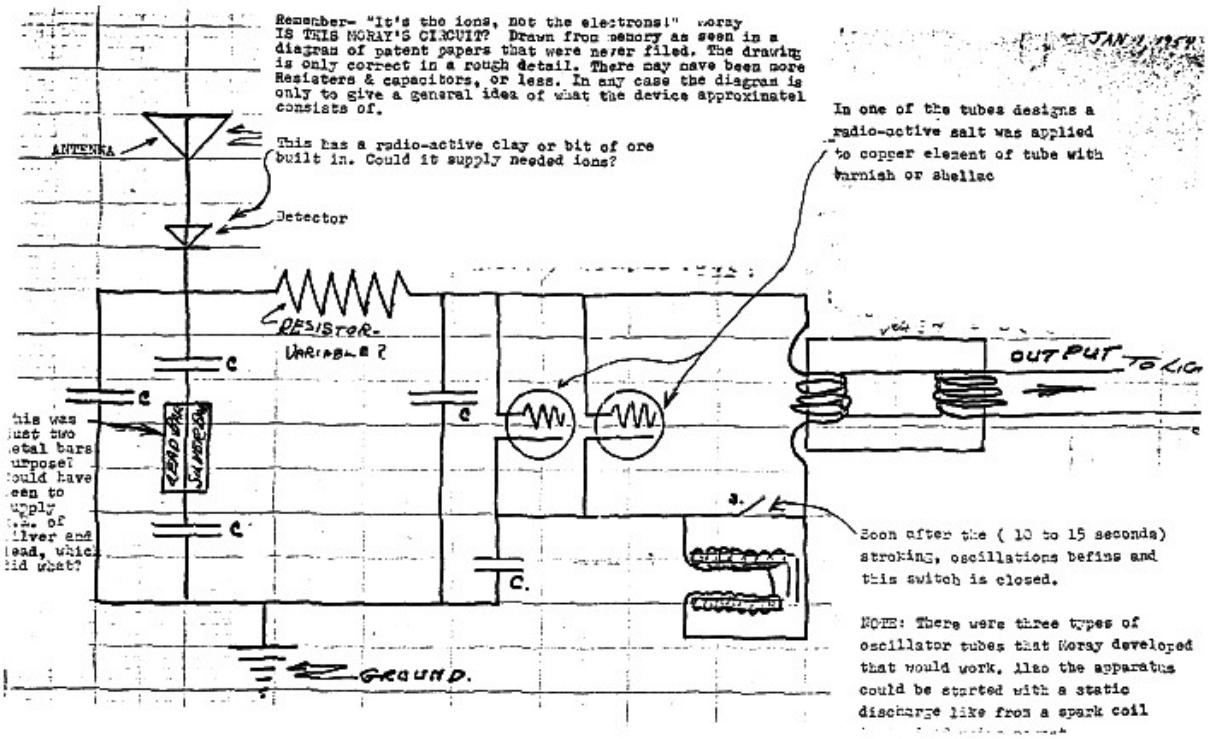
This apparently first and very successful resonant circuit atmospheric energy harvester used some unique components in his circuit, and also never fully explained how his device worked. For these reasons, no one ever managed to copy his design. One key device was the world's first semiconductor diodes, made from "Swedish rock" germanium, which even Moray, a mineralogy and crystallography materials expert, was never able to adequately synthesize once he ran short of the original natural material. Another device was his specially made vacuum tubes with unique sounding operation that I won't attempt to describe here. (He made three models of the tubes, that all worked in the energy devices.) Moray described the energy being harvested as "radiant energy" as he was aware that it was

radiant energy that ionized the air, but it seems he thought it was the atmospheric ions he was harvesting.

Soon corrupt interests sabotaged Moray's efforts to patent anything at all, and tried to have him killed, apparently on three occasions. Moray had become suspicious and carried a small gun, and he evidently kept his wits about him and was a very good shot, because he came out alive on all three occasions. Finally a jealous person smashed his machine, and the work came to a sudden inglorious end. (Moray went on, among other fascinating projects, to invent/design improved (vacuum tube) radio receivers and amplifiers for well known companies such as General Electric and Sylvania, which units graced many homes up until the early to mid 1960.s when the first small, portable Japanese "transistor radios" came out, followed by more modern solid state stereo equipment in the late 1960.s. But I digress.)

A researcher tried to draw Moray's energy harvesting circuit schematic from memory from seeing it in the patent application. (Moray's patent applications were denied on specious grounds, and the contents of the application envelopes mysteriously disappeared from the patent office.)

Of course the chances of it being mostly correct are small. The person didn't know what the bimetallic lead/silver piece was for, and its placement between two capacitors (according to his memory) is even more puzzling. (Doubtless all explained in the patent.) One recognizes a potential L-C oscillator involving the two tubes with the lower coil and switch, which (having no source of power until the unit was working), had to be "stroked" with a magnet to get it started, at least in the early units.



Today's problem is that while atmospheric charges are better known, the resonant oscillations technology for harvesting them effectively has been little known or misunderstood and has never spread. Only recently with the advent of the internet has it started to become somewhat easier to separate facts from myths, and to find nuggets of information about Moray's work and other more recent apparently successful work. Still those with nothing real to offer, perhaps some of them shills for the corrupt, seem to shovel out all the disinformation they can, and by perpetrating so many convincing and unconvincing hoaxes, make it seem like it must all be hoaxes.

Yet we understand that the atmosphere is in fact full of ionic energy. And that Moray's energy harvesting device worked to the extent of at least several kilowatts, day or night. Today we have a wide variety of electronic devices that were unavailable to Moray. One person described the tubes as "oscillating tubes", and there are lots of ways to make an oscillator. We have both germanium and silicon diodes readily available, and active rectification if extra-low forward voltage drop proves somehow instrumental to the harvesting. Surely in the 21st century, Moray's pioneering work can be explored and expanded upon. Even if there were no other, this well known - if not well understood - form of plentiful

free energy is all around us, seemingly just waiting for appropriate circuits to be invented or reinvented in order to harvest it!

Correction: The air-core coil I got last month (left) is about 25 microHenries, not 25 nanoHenries. (Small slip, BIG 1000x difference when designing a circuit!)



On the 6th I searched youtube for "Atmospheric Electricity" and found a channel called "LaserSaber", who had done some experiments in that area, using a hexcopter to lift wire high up into the air. The most interesting video was one where because of a high voltage electrostatic motor (with considerable torque!) that he had built and shown on youtube, he was invited to visit *Ion Power Group* which has been working on harnessing atmospheric energy for 10 years in Florida. I was impressed with several things, not the least of which was the many kilovolts coming down from the 4 antenna wires 130 feet up, strung between 4 poles in a very large square. The danger of working with such high voltages was impressed on me many times in the video, from heavy rubber gloves, to 6" long ceramic insulators, to a 1000 to 1 reduction voltage probe (reading ~9 = 9000 volts, or ~12 = 12000 another time), to a continuous thick arc bridging a gap of nearly an inch on a turbulent day, to 4' long sticks used to hold and connect wires, to a giant shower of sparks that lit the room from connecting something wrong. And they spoke of 250000 volts on a stormy day!

But they were using passive collection. Their web site mentioned the collection of energy "skyrockets by many orders of magnitude" when the atmosphere is disturbed, but not that they had any thought of electromagnetically disturbing it to get the same effect. They had big, high antenna lines and got

energy, and used some streaming wires with graphene that formed micro-spikes that would multiply their charge collection by 10 via the corona effect, but it still wasn't the sort of high energy Moray was collecting with what appeared to be resonant circuits -- except on stormy days, when they got up to over a kilowatt. Moray got several kilowatts any day.

I plan to try out Moray's route... with considerably more caution than I was thinking of and a much smaller, lower antenna. (an aluminum plate, tied to my chimney about 40' up?) Evidently it could still make potentially lethal voltages. But if I can make the resonance technique work, it should still produce very useful power instead of milliwatts.

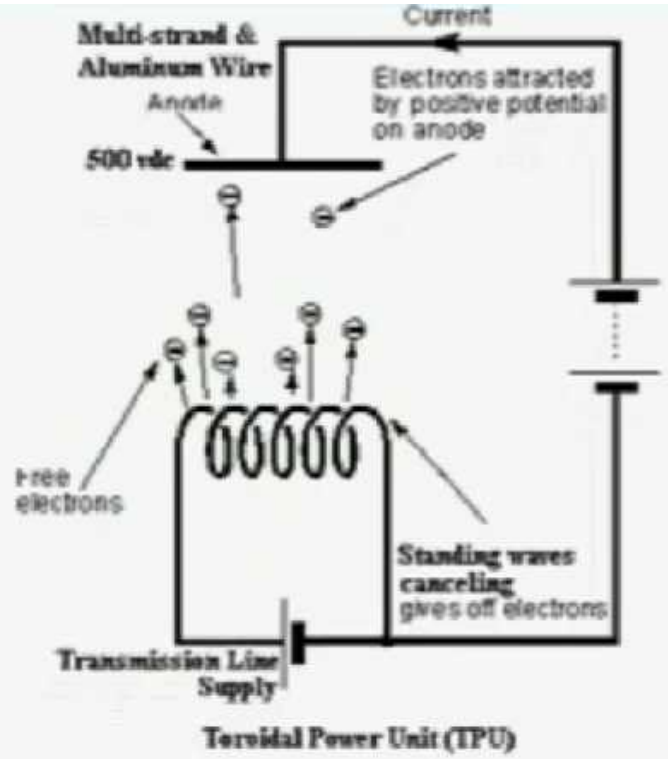
It occurred to me that a good place to start might be to connect a diode or a diode bridge and a microampmeter (big needle, -50 to +50 µAmps) between an antenna and a ground wire and see what DC current might flow. I could also hook the oscilloscope in there and see the actual voltage waveforms instant to instant. With all the nearly "mystical" talk about germanium, I got four 1N34 germanium diodes for the bridge. From what I've been seeing the difference between .3v (Ge) and .7v (Si) forward drop should be a drop in the bucket. And yet...

Then there's spark gaps. Apparently blue sparkles could be seen running down Moray's "Swedish stone" germanium diodes. Did the germanium crystals in his stones form tiny spark gaps? Is a spark gap a diode? Maybe sort of. Depending how it's made, it should be more prone to arcing in one direction of voltage than the other, again by the corona effect. There's no current at all until the arc begins. (Then when current starts to flow, does the forward voltage drop drop to zero?)

But I decided to make a spark gap as a safety device to protect both my circuits and myself against overvoltage. On the 9th I came up with a tentative plan for a one: an outside surround of metal such as a round or square pipe or tube, with a gold surface, perhaps simply plated with gold, arcing to something like a stainless steel sewing needle. The needle might be placed in-line, parallel, with the surround metal, just an 8th, 16th or 32nd of an inch (or whatever seems to work at a desirable voltage) from one edge. The surround metal (anode) goes to the antenna at the top, and the needle (cathode) is grounded. Where most metals will corrode and form an oxide layer of some sort under positive voltage (anode) conditions that will hinder arcing, gold, almost alone, is very difficult to oxidize. (I wonder if my ~2004 Caswell Plating gold brush plating solution will still work?) The metal tube could be inside an insulating plastic or ceramic pipe, and the needle could be mounted in a big ceramic block... after seeing all the arcs and sparks at Ion Energy's facility, I want to try hard not to electrocute myself. Or get the radiation(?) burns that Moray got on his hands, that were probably the same as those I seemed to be being warned of in a dream. Maybe I should make some ceramic parts first in my mini-kiln. And maybe the antenna will go next after the spark gap to a big knife switch... enclosed in something... that I operate from a distance with a plastic rod. It can also have a shorting switch to ground to prevent high voltage from getting to the circuits as the antenna is switched in - assuming I *always* remember to turn the short on before activating the antenna. But relying on memory for the switch-on sequence isn't a reliable technique. Maybe if opening the knife switch automatically closes the shorting switch. I think I like that idea. Well, doubtless I'd have to make my own switches regardless to get that to happen!

And yet, from the passive designs I've seen, the voltage builds quite gradually in the circuit when the antenna is connected. Should it not be possible to make, eg, a 12 volt DC output unit, and the oscillator shuts off momentarily or something shunts off the excess if the voltage gets too high? Except at the spark gap and the knife switch, with the circuit turned on there should be no high voltages. An inverter can be used to change the 12 VDC to 120 VAC/60 Hz as required.

On youtube I found an explanation of sorts for active use of a "spark gap" of sorts... a "Toroidal Power Unit" ("TPU") was shown as being kind of like a vacuum tube effect with no vacuum, the electrons flying toward a high voltage 'plus' plate.



Just how or whether this fits in I'm not sure.

I decided to use an "extension cord", a cable having an outer sheath, for the antenna leed wire. I could drill a hole in the roof near the chimney and feed it through. First I selected an aluminum plate from my collection for the antenna. Next question was, what to use for an insulated "mast" to hold up the antenna. I would tie this to the chimney. (Say, how come I've never heard of people getting shocks putting up or hooking up, eg, a TV antenna?)

Then on the 9th I thought that if the Ion Power Group was using spikey bits of graphene not only to make lots of little spikes but also to increase surface collection area in general, maybe an aluminum window screen - lots of fine wires - would be better than a plate. Or even such a screen with some graphite fiber wrapped around it?

On the 10th a considerable search with some clean-up found the ±50μAmp meter, and a cable for the antenna connection, but not the big knife switch. Further searching over the next couple of days was to no avail. Who would ever dream I'd ever actually want to use that antique?

Soon I decided I'd have to make my own special double safety switch: Opening the antenna knife switch would automatically close the safety ground-short switch to protect the electronics and perhaps myself. Only once the antenna switch was reclosed could the ground short switch be opened, allowing the antenna voltage to rise to power up the circuit. The electronics itself would have some means of preventing the antenna voltage from rising too high. So the electronics need not be designed for high voltages, except perhaps for the oscillator to 'stir' the air.

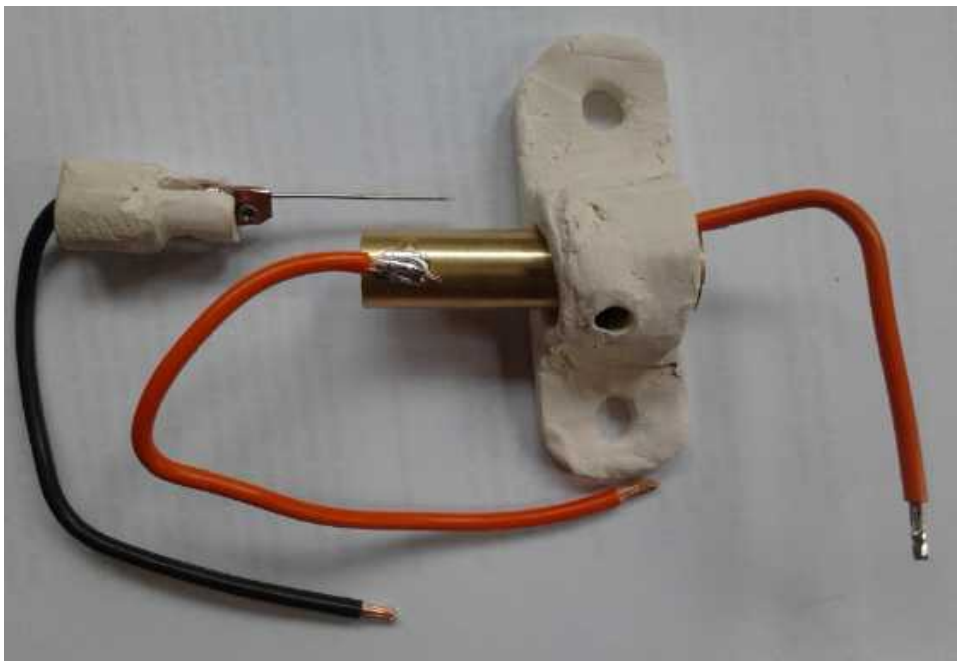
Then I realized that the antenna never needed to be disconnected. If it was grounded everything was safe. It just needed a simple knife switch, but to ground, not to the electronics, which could always remain connected. I still couldn't find it. Perhaps I actually threw out something that looked sort of interesting, just because I couldn't think of a use for it? On the 12th I gave up and bought a new large size switch, a battery switch from an automotive place. It's probably better because the wires (in particular the antenna wire) are enclosed.

On the 14th I went to buy an aluminum screen. But I got a thin, solid aluminum "gutter guard" instead. It was bigger in area than my aluminum plate but it had holes to increase the surface area and to let some wind go through. I thought about the idea of insulating it (it was already painted), more particularly with a high dielectric constant insulation. On the 15th I thought of the static cling of transparent tape. Since I couldn't see wrapping it with countless skinny pieces of that, I used packaging tape, which also has a lot of static cling. If it makes all that static as it's unwound, surely it has the right characteristics? (So much for the holes in the aluminum!) Then I mounted this plate on a 5 foot PVC pole, clamped that to a piece of wood, connected the cable, and tied it to the chimney at the peak of the roof with a few wraps of rope, about 40' up from the ground. I drilled a 3/8" hole through the roof, next to the peak and next to the chimney, and pushed the cable through, into the attic space. The next day I



donned gear and ventured into the attic (full of blown-in-fiberglass dust, cellulose fiber dust, rat droppings et al) and ran the wire through to the solar equipment closet below.

Cleaning the closet occupied the next day's work session. It was full of plaster and drywall compound from fixing the wall when I first did the solar stuff along with crap from the holes for wires into the attic, some firebricks and other bricks I had set dry cell batteries on for fire safety, batteries lying around, and various bits of electrical stuff, both on the floor and the shelves. I did a lot of vacuuming. None of it my favorite work. But I think I'm digressing from the story here. Comes of writing late at night.



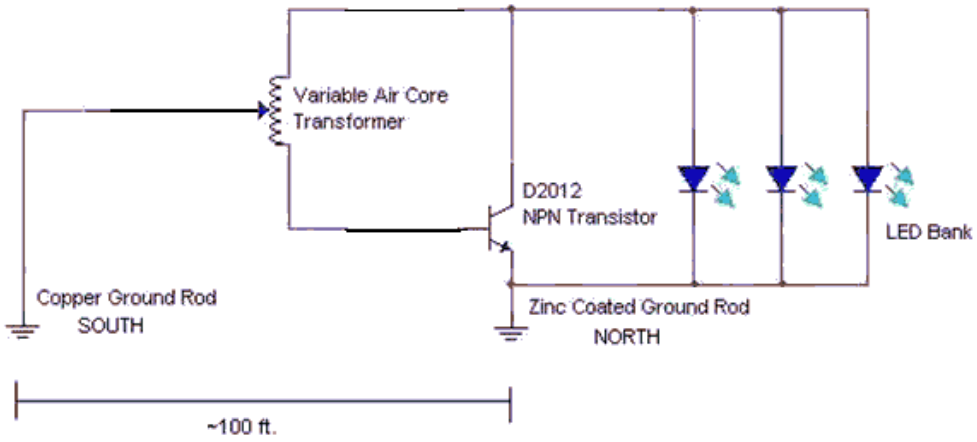
On the 18th I formed a couple of ceramic clay pieces for an insulator to hold the spark gap. I left them to dry overnight, then fired them in the mini kiln.

On the 19th I voted, marking my ballot 3 - 4 - 1 - 2 in my order of preference for the candidates. No 'illiterate's X' ballots for me! Hopefully it'll at least give the vote counters something to think about!

Then I contrived to mount the spark gap and the antenna grounding switch on the wall in the closet, and connected the antenna. Then next day I added a couple of wires to connect to a nearby circuit and put in a small shelf to hold a circuit 'breadboard' to try things out. I measured the voltages from the antenna: .34 VAC, and -.012 to -.02 VDC. Not only were the voltages trivial, the DC component was backward compared to expectations. Quick attempts to hook up diodes and 2.2µF capacitors seemed to kill it. It turned out to be the 2.2µF ceramic capacitors, which *should* have virtually no leakage. A .1µF capacitor charged up so slowly to over 1/2 a volt (still backward polarity, with the diode either way around!), that simply connecting the voltmeter - doubtless quite a high impedance unit - caused the voltage to rapidly start dropping instead of rising. Variations on the circuit seemed just as futile. Had I made a mistake by insulating the antenna? It certainly appeared, as many have found, that a simple diode-capacitor circuit doesn't bring in much power. Others have had better (less trivial?) success on youtube. The possibility remained that a resonant oscillator would revolutionize the picture.

The next morning (21st) I looked again at the "Tesla Cult" circuit. (but remember "ground rod south" was replaced by "antenna".) My antenna voltage of only .34 VAC was hardly enough to overcome the forward voltage drops of semiconductors. It didn't even seem to matter which way around the 1N34 germanium diode was. But the coil with the tap, the "variable air core transformer", would magnify the voltage by the ratio of:

the whole coil

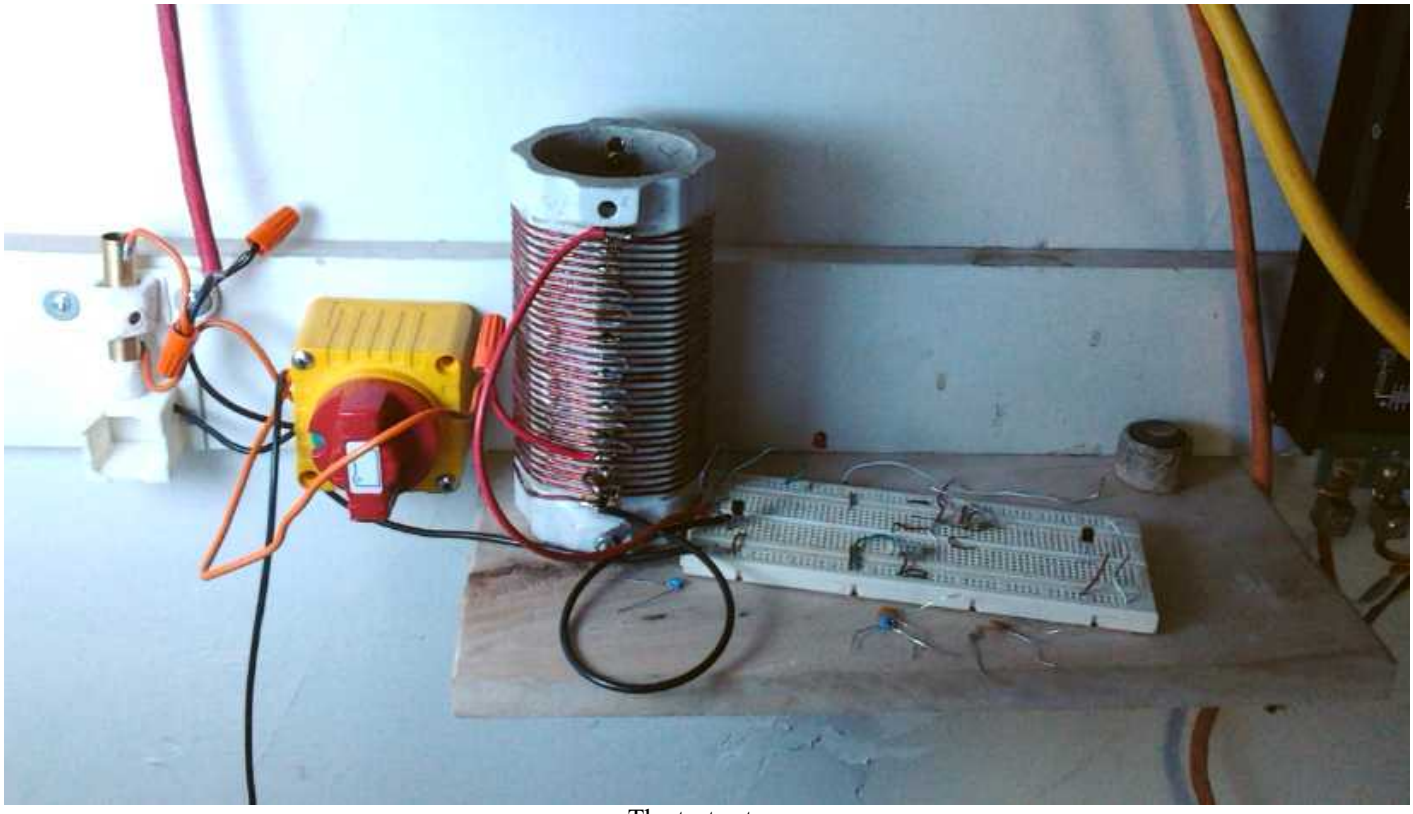


the tapped portion.

If that was (say) 6 to 1, the tap 5/6 of the way to the bottom, it would be .34v * 6 = 2.04v making the voltage high enough to work with. The already feeble current would be similarly decreased by 6x, but it seemed the voltage was too low to make good use of whatever current there was anyway, so it's probably all gain. Here was the first key: the coil makes for not just a resonant circuit, but an AC/RF voltage multiplier. Here we get the impression that it may be more the AC component of the atmospheric ions that is important than the DC one, which can't be amplified by a transformer. But maybe it's the combo. But when I connected the coil, the AC voltage dropped to zero. That suggested a low frequency rather than RF.

Being busy with other things, it wasn't until the 31st I brought over the oscilloscope to better see what was coming in. With no other connection to the antenna, the DC component was pretty much imperceptible and the AC component was just mostly 60 Hz hum, .4V peak to peak - no surprise in a wired house. There was another sinusoidal waveform on top of it at about 1MHz, but only about 20mV peak to peak. This could have been a nearby AM radio station - in fact the signal's amplitude modulated probably about like music playing. Something else briefly appeared at regular short intervals that seemed to be about 10 MHz, but it seemed to be synced to the radio station. Nothing seemed anything like a random sort of atmospheric noise, but it had an 'artificial' look to it. I saw no lightning from distant thunderstorms but then it was October, and we get less lightning on the west coast than anywhere else on Earth. Where then was this atmospheric energy?

Nothing ventured nothing gained, it was time to breadboard the oscillator. I thought I'd start with Tesla Cult's circuit since it was simple. I plunked in the components and connection wires. Nothing seemed to happen. That was as far as I got. Next will be a real oscillator with a tuning capacitor to vary the frequency and a battery to provide initial power to make sure it's working.



The test setup.
The red shielded wire comes from the antenna. The black wire is grounded at an electrical outlet. The spark gap to ground is to help protect circuits and ensure safety should high voltages actually become present if it works. Likewise, the red switch shorts the antenna to ground. I screwed a piece of wood into a board in the closet wall to make a small shelf for trying out circuits.

(The wires on the far right are from the solar PV panels and the black box is the Zahn DC to DC converter that converts the solar panels' output to 14.0 volts to charge NiMH and PbPb batteries and for the 12V receptacles around the house, so far used for LED lights and the Peltier fridge.)

In early November I read that Moray's later energy units worked in locations where they couldn't be tapping atmospheric energy, and without an antenna or a ground. It seems he must actually have been tapping "lambda ray"/"short space ray"/"VHE gamma ray"/"zero point" (surely all the same thing) energy after all. Why would he get radiation burns from atmospheric electricity?

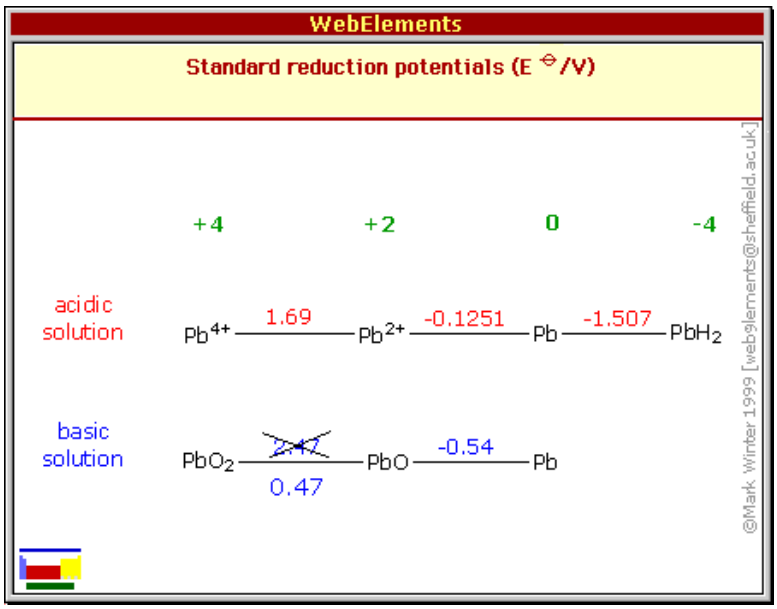
Frankly as I write, I realize that I still have virtually no success and far more questions than answers. Is atmospheric energy worth pursuing or just a curiosity? Or is the seemingly elusive lambda ray energy the only practical pursuit along these lines?

I think that a spark gap, like Moray's sparking mineral diodes and like the "TPU" circuit diagram above, has some valuable if not fundamental purpose in capturing lambda ray energy. But if so, just how and where should it be employed? Perhaps the "TPU" illustration is a clue - maybe it just makes a high frequency, high voltage diode?

Well, perhaps I'll try a bare metal antenna next, as the dielectric coated one doesn't seem to do much of anything. One thing sure: if anything I try yields success measured in tens of watts or better, I'll document every aspect well so hopefully everyone can achieve similar results.

Electricity Storage - Turquoise Battery Project Etc.

Lead? Lead?



On the 30th I was thinking about the nickel-nickel cells that keep having more self discharge than nickel-manganese, which are double the voltage. Something I don't understand is going on there. Then I thought of zinc, that elusive metal that works so well... except for gradually dissolving during discharge (and sometimes shorting the cell) and so giving short cycle life.

Then I thought of lead, similar to zinc in some ways, but it doesn't dissolve even in sulfuric acid. I looked again at the reduction potentials diagram. (the one that had steered me so wrong in the past by having a wrong value printed on it.) In sulfuric acid, metallic lead discharges to lead sulfate, PbSO4. This substance gradually forms larger, non-conductive crystals that can't be recharged, helping to give lead-acid batteries their well known limited cycle life.

But in alkali the chart shows it discharging to lead oxide, PbO. (or more likely to lead hydroxide Pb(OH)2 per the Pourbaix diagram below. It make little difference which it is.) This (surely?) won't have such a problem. And the reaction chart is dead simple - no branching tree or dissolved ion or non-conductive states. (We know from lead-acid that batteries that PbO2 (or, surely, Pb(OH)4) is a conductor.) So unlike nickel-iron, I would think it shouldn't have to be used at pH 14 to prevent irreversible corrosion to a non-conductive oxide form. It should thus have a very long cycle life. As we all know lead has a high molecular weight (207.2), which does little good for energy density (theoretically 259 WH/Kg for the metal)... but might it work for me better than things I've tried? Might nickel-lead provide a simple chemistry for small scale production which has eluded me so far?

The reaction voltage of metallic lead to valence 2 is very low in acid. But in alkali it's over 1/2 a volt. A nickel-lead cell in KCl solution at pH 12-13 should work with a voltage of about +.85 - -.54 = 1.39 volts, or maybe somewhat less. If it worked well, I'd be farther ahead than I have been so far!

I decided the thing to do would be to take apart a lead-acid battery and disassemble some of the plates. I have a simple candidate in a small one about the size of a 'D' cell that has been sitting around for years and has just turned up from a dusty cupboard. Or maybe just find a chunk of lead for a quick experiment.

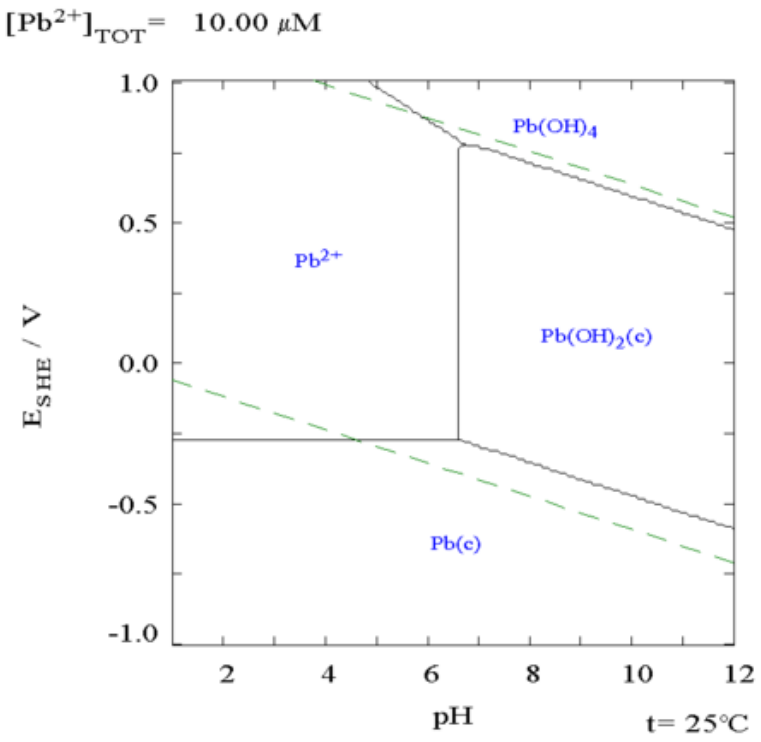
One is tempted to look above lead on the periodic table for a lighter element in the same column. But the next one up is tin, which has many soluble reactions. Above that are germanium, then silicon, then carbon. Carbon, and probably silicon, wouldn't oxidize. My mind balks at the idea that germanium might work even without checking it out. Lead seems to be unique.

A separate possibly useful lead reaction is Pb(OH)4 to Pb(OH)2 for the positive electrode. It moves 2 electrons where simple NiOOH to NiOHOH only moves 1. In alkali the theoretical reaction voltage is a little lower than NiOOH. The high atomic weight gives it a theoretical energy density of just 200 WH/Kg (at pH 12, counting the atomic weight of three 'OH's), versus 289 for the NiOOH (at pH 14).

There are two ways this *might* be useful in place of NiOOH. The first is *if* it has significantly better percent utilization of the atoms. Then it might outperform the nickel, which I've heard somewhere gets around 90 WH/Kg in actual use. The second is *if* a solid piece of lead reacts on the surface without the reaction penetrating deeper, ie *if* the oxide layer that forms is solid and doesn't dissolve. In that case, a lead (Pb) wire in the positrode wouldn't dissolve, and the current collector and connection wires can be lead (as they are in lead-acid batteries) instead of graphite. That's not lighter but it's simpler to make

and promises better internal and external connections. (Potentially lead leeds would work for nickel hydroxide electrode current collectors in KCl, too. IF it works that way.)

But with decreasing pH, while still on the alkaline side, the lead voltage rises more gradually than that of the nickel types, so the cell voltage will be somewhat lower. Since that probably means both lower voltage and lower amp-hours for lead, and as it seems to be finding a good negative electrode I'm really having trouble with, I'll probably leave the lead positrode idea well enough alone. Except maybe I'll try out a lead terminal wire and see if it stands or dissolves. It would be much easier to seal a wire through the case than the graphite sheets.



Pulse Charging for Lead-Acid Batteries

I've experimented a lot with using sodium sulfate to help restore lead-acid batteries. Another thing to do is to try using a high frequency "pulse charging" charger, which as I have discovered often makes the difference. The merchant said he's brought more 'dead' batteries back to life with the "Xtreme Charge" charger he sells than anything. It's only 2 amps, but it helps gradually break up the lead sulfate crystals that passivate the plates.

Be sure to get one that actually does only pulse charging, or at least allows it as a user selectable option. I recently bought two cheap ones that say "pulse charging" on them, but they only do pulse charging if *they* decide to - I can't make them do it, and indeed they have never entered the pulse charging mode they claim to have on any battery I've tried.



The top “Xxtreme Charge” is a good model that does strictly high frequency pulse charging. (bought locally at “Battery Direct”)
Its biggest failing is that it claims badly discharged batteries are "bad" and won't start charging them. Use another charger to get them started.

The bottom “genius”(?!?) one claims it has pulse charge, but it won’t go into pulse charge mode and so it's pretty useless.
It *claims* it'll go into pulse charge mode when *it* detects the need to do so... but how can it really know?
It doesn't do it or let me select it on any crappy battery I've tried. (bought at Canadian Tire)
...It's another "would have been useful" product turned into crap by another manufacturer not disclosing useful information (like what material something's made of, etc) or (as in this case) not allowing the purchaser to make his own choices about how to use it.
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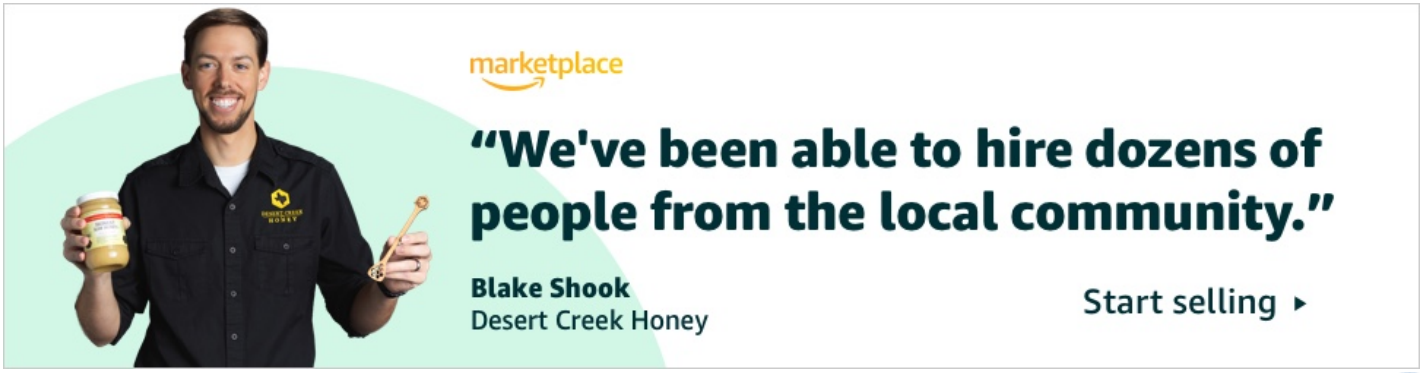


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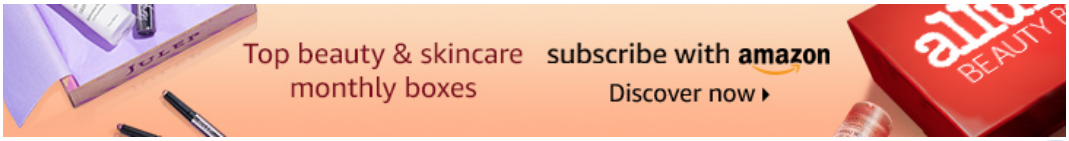
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How to Connect Coaxial Cable Connectors

Three Methods: Initial Steps Strip The Cable Using A Crimp-Style Connector

Coaxial cable is any cable that has an inner wire shielded with an outer conductive sheath by a dielectric (non-conductive) material. Here's a look at how to attach your own connectors to cable TV coaxial cable.

Method 1 Initial Steps

1. **Determine your cable size.** Cable terminology can be confusing. Look on the side of your coaxial wire for the size designation. In most homes, the two most common sizes are RG-6 and RG-59.
   - RG stands for "Radio Guide." The numbers of the various versions of RG cable refer to the diameter (59 meaning .059, and 6 meaning .06, etc) and internal characteristics of the cable, including the amount of shielding and the cable's attenuation, which refers to how much signal loss there is per length of cable.
   - You may also see the term RF used with these cables, which stands for "Radio Frequency."
   - Most non-industrial coaxial cable is now known as RG-6, although the previous thinner lower-quality standard of RG-59 is still used in some applications and older homes. Commercial installers may use a thicker RG cable, like RG-11(which is only used if the distance from the source tap to your point of termination at the home is greater than 200 feet)
   - RG cables used in homes for ordinary purposes should be 75 ohm (RG-6 or RG-59).
   - Be aware that all cables (and their connectors) come in a variety of qualities. Get the best quality cable you can.

2. **Choose the right connectors.** Most connectors for home video installations are made with F-Style connectors. However, it is possible your system uses N-type connectors.
   - Be aware that there are several types of F-type RG-6 cable available, primarily screw-on and crimp-style connectors.
     - Screw-on connectors are easy to use, but are less secure and can leave a small air pocket. Some people believe this may affect your signal quality.
     - Crimp-style connectors have two parts: a ring (or crimp) and a terminator. They are typically more difficult to install, but can attain the greatest lengths and best connections when used correctly.
   - Know that to make a connection you will need a male and a female connector of the same type.
     - Male connectors have the center wire sticking out, while female connectors have a space for the center wire to stick into. Be sure to use the opposite gender to the connector you will be making. Most cables end in male connectors.
   - Use an SMA (sub-miniature Version A) connector for very small coaxial cable.

Method 2 Strip The Cable

The first step to attaching your own connector is to prepare the end of the coaxial cable.

1. **Cut the cable flush.**

2. **Trim the outer cover (usually black rubber) back 1/2".**
   - Be very careful not to cut into the metal braiding directly beneath the outer housing. The braiding may be both "loose" wire and a foil-like metal present in shielded wire.

3. **Carefully pull back the inner braiding (second channel) outside the outer cover.** Check to make sure none of the braided wire gets wrapped around or touches the copper center conductor.

4. **Trim back the (usually white, but may be clear) dielectric plastic from the inner core cable.**
   - Be absolutely sure not to scratch or nick the center conductor. Any damage to this conductor can severely impact your signal.

5. **Push the connector down over the cable end so that the copper core of the coaxial cable sticks out.**
   - Be sure the dielectric (aluminum foil) is trimmed so that it does not enter into the terminator of the connector.

6. **Screw the connector into the end of the cable.** The thread will cut into the outer housing and wrap the shielding weave, making a tight fit.

Method 3 Using A Crimp-Style Connector

This is another method which can be used to connect coaxial cable connectors.

1. **Place the crimp ring over the cable end.**

2. **Trim the outer cover back about 1/4".**

3. **Trim the shielding, wire wrap and dielectric back to the bare inner wire.**

4. **Leave about 1/8" of dielectric.**

5. **Place the terminator over the end of the wire so the copper core sticks out through the hole.**

6. **Push the crimp-style connector down into the cable end so that the tube of the connector goes between the foil and the outer housing.**
   - This can be very difficult to do. Try holding the cable end with a pair of pliers, or clamping it in a vice. Try not to twist when pushing down.

7. **Crimp the ring around the outside of the cable.**

8. **Trim any loose wires.**

9 **Cut the inner core wire flush with the end of the connector.**

10 **Tug on the connector to make sure it is attached.**

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Community Q&A

Will my router need to be hooked up to one to connect to the internet?

wikiHow Contributor

Although the thin twin cable probably isn't as good as even normal TV cable, it's likely to work well enough, unless your signals are exceptionally poor.

Not Helpful 1 Helpful 5

Can I connect sky cable to a digital aerial?

wikiHow Contributor

Yes, but the thin twin cable probably isn't as good as even a normal TV cable. Still, it's likely to work well enough, unless your signals are exceptionally poor.

Not Helpful 5 Helpful 7

Can I connect a second internet provider to my wall outlet?

wikiHow Contributor

You cannot short circuit the feeds from two providers together (i.e have two providers coming out of the same socket). However, you can have two sockets on the same mounting plate, which is the same electrically as having two separate sockets -- one for each provider.

Not Helpful 0 Helpful 0

Tips

- If you have high speed internet and more than two TV's, make sure you use a high quality RG 6-type connector. When putting a connector on the cable wire, proper preparation is essential to get a clear picture as well as a good seated connection for the cable modem. Use a compression style connector available at any popular home improvement center. Also, when preparing the end of the wire, be sure not to "score" or nick the copper center conductor as this can cause problems with your internet such as intermittent connectivity and packet loss.
- You can buy crimpers, cutters and strippers specially designed for coaxial cable in certain diameters. These tools do take some practice to learn how to use and you do not have to use special tools to make these connections. Regular strippers will do as long as you're careful.
- Do not use the screw-on style F-type connectors. Cable signal will "leak" out of a cheap or poorly terminated connector such as these. This can cause unwanted signal "ingress" to get into the cable line and cause odd distortions such as vertical lines, dash lines moving horizontally across the screen and "beats," or little white dots randomly over the entire screen.

Warnings

- Professionals use compression fittings on coax with a compression tool that is not much more expensive than a crimper. These are used now instead of crimping as it makes a more waterproof seal and affects the signal less at the joint point.
- Make sure you use a good connector. Do not settle for a less than perfect job. Cable TV signal can leak out of bad connectors and interfere with lots of devices that use RF technology (including airplanes). Furthermore, it can be an FCC violation if too much signal leaks out.
- If you are unsure of how to do this, leave the job up to the professionals at your cable provider. Most offer relatively cheap rates, especially when compared to electrical contractors.

Things You'll Need

- [ ] Wire cutters
- [ ] RG-6 cable strippers
- [ ] Channel locking pliers
- [ ] RG6 connectors
- [ ] Crimper
- [ ] Wire strippers

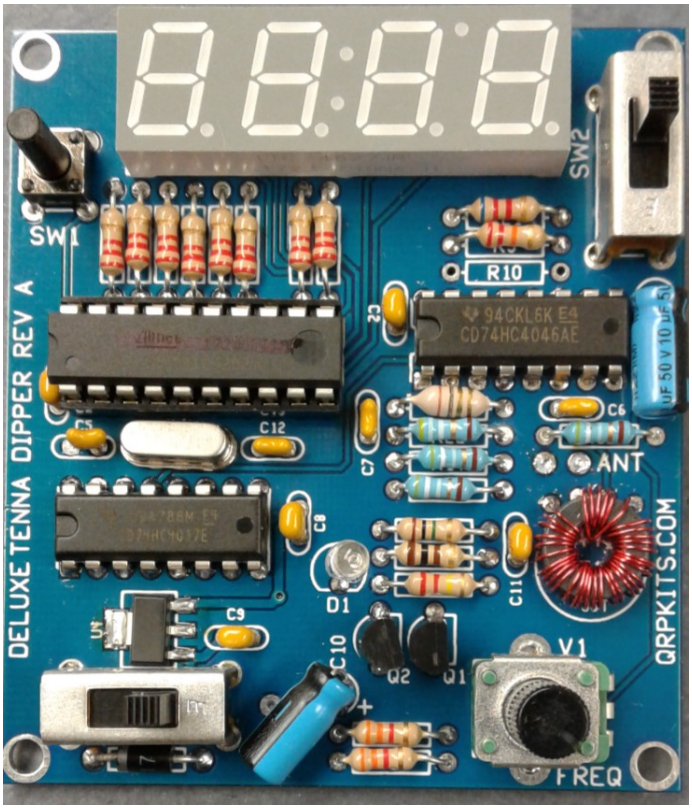
Sources and Citations

- http://www.bluejeanscable.com/articles/rg6.htm - All about RG
- http://en.wikipedia.org/wiki/Coaxial_cable - About coax.

The Deluxe Tenna Dipper

Design by: KD1JV

Distributed by: Pacific Antenna, www.qrpkits.com



The "Tenna Dipper" provides a simple means of determining the 50 ohm resonant frequency of an HF antenna or ATU (Antenna Tuning Unit). The small size and battery operation makes the unit ideal for use in the field.

Features:

- Wide tuning range: ~3 MHz to ~30 MHz in two ranges
- Four digit LED frequency readout

Usages:

- Eliminates the need for a transmitter and SWR bridge when:
  - Trimming length of resonant dipole antenna.
  - QRM free adjusting of antenna tuners
  - Quickly adjust short, portable vertical antennas.

How it works:

A voltage controlled R/C oscillator generates a 5 volt square wave signal. This signal drives a resistive Wheatstone bridge. One leg of the bridge is the "unknown" resistance, the antenna. A wide band step up transformer is connected across the bridge to detect the signal produced when the bridge is unbalanced. This signal is farther amplified by a Darlington pair transistor amplifier. A high brightness LED is used to visually indicate the current in the collector of the amplifier. When the antenna impedance at the unknown leg of the bridge is equal to 50 ohms, the bridge is in balance and the LED will go out. Hence the name for this device, the Tenna Dipper, as we dip the brightness of the LED to find the 50 ohm match.

Using the Tenna Dipper.

Finding the resonant frequency of a coax feed dipole antenna:

Simply connect the feed line to the Tenna Dipper and adjust the frequency until the SWR indicating LED goes from bright to very dim or completely out.

Then read the frequency on the display.

This is the 50 ohm resonant frequency of your antenna.

Adjusting an antenna or ATU to a specific frequency (or band)

Connect the feed line which will go to the transmitter to the Tenna Dipper and set the oscillator desired frequency.

Now adjust the antenna or ATU to make the SWR indicating LED to be very dim or go out completely.

The Tenna Dipper is very handy for adjusting short vertical antennas such as the PAC-12 or MP-1.

Set the Tenna Dipper frequency to the desired band and connect to the antenna.

You can watch the brightness of the LED from a distance, so you don't have to run back and forth between the antenna and the 'Dipper.

If the resonant frequency is below the frequency you want to use, you need to shorten your antenna to move up in frequency.

Or, if the resonant frequency is too high, your antenna needs to be extended in length.

Do this in small increments and retest.

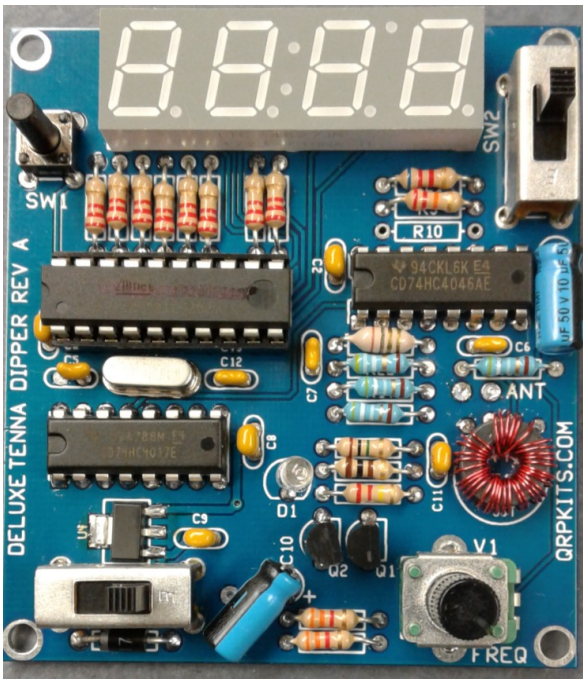
For dipoles, you can sometimes coil the wire into a tight coil at the end rather than cutting.

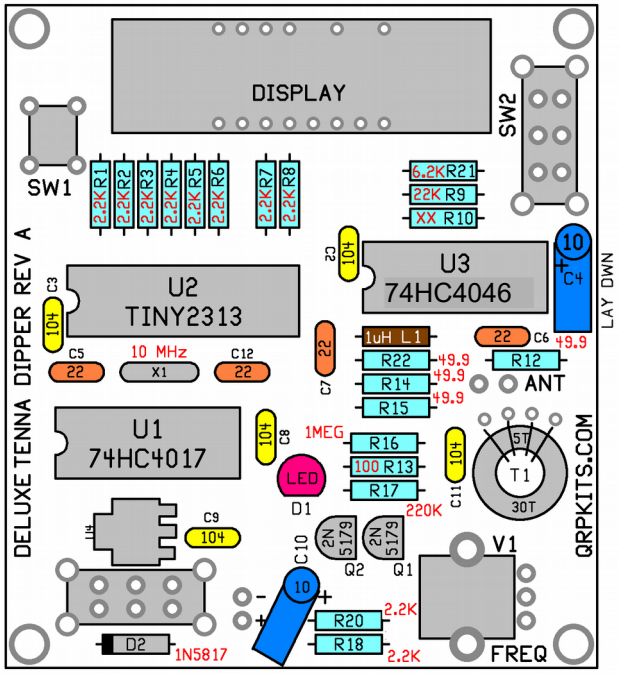
Since the proximity of your body to the antenna can affect the match, once the match is close, be sure to step a few feet away from the antenna to make fine adjustments and find the prefect match.

Parts list:

√	QTY	Part number	
	1	CD74HC4046AEE4	
	1	CD74HC4017E	
	1	ATTINY2313-20PU	
	1	1N5817	
	2	MPS5179	NPN RF TRANSISTOR
	1	MCP1703-5002E/DB	5V LDO REG
	1	4 DIGT 7 segment LED	
	1	T-1 super bright red LED	
	1	10 K LINEAR POT	9 mm potentiometer
	2	DPDT SLIDE SW	
	1	6mm / 13mm TAC	PB Switch
	1	RFC 1 uH	
	1	FT37-43 TOROID	
	1	10.00 MHz HC49US	Crystal
	5	49.9 OHM 1 %	
	1	100 OHM 5% 1/4W	
	10	2.2 K 5% 1/4w	
	1	6.2 K 5% ¼ W	
	1	22 K 5% 1/4w	
	1	220 K 5% 1/4w	
	1	1 MEG 5% 1/4w	
	4	22 pdf NPO 0.1” LS	
	5	0.1 ufd MONO X7R 0.1” LS	
	2	10 ufd/16V ALUM ELECTRO	
	1	20 pin DIP socket	
	1	2 feet # 30 magnet wire	
	1	BNC Jack	
	1	RED FILTER FILM	2” X 0.75”
	1	CIRCUIT BOARD	
	1	DECAL SET	

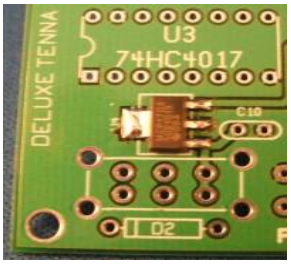
Assembly:





Mount U4 first

Note: This is a SMT (Surface Mount) part.



- First lightly tin one of the three solder pads which are in a row.
- Place the part over the pads, (hold part with your needle nose pliers) then use the tip of the soldering iron to heat and gently push on the lead over the pad which you just tinned.
- Then heat and flow a little solder to all of the leads of the part.

Next mount all the resistors: (plus RFC and diode)

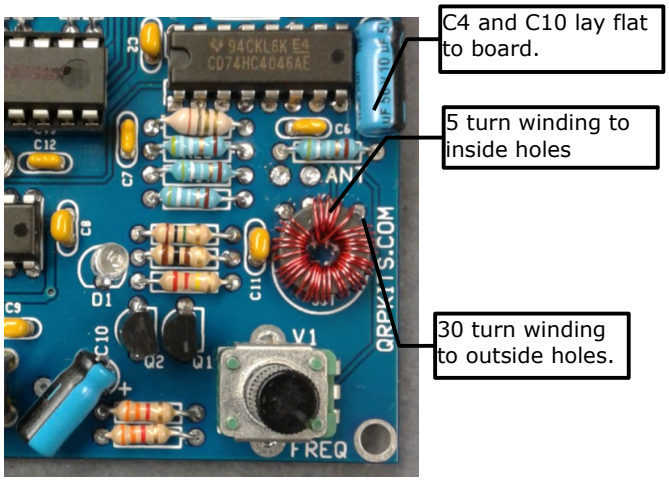
	Location	QTY	Value	Color code
	R1,2,3,4,5,6,7,8,18,20	10	2.2 K	Red/Red/Red/Gold
	R21	1	6.2 K	Blue/Red/Red/Gold
	R9	1	22 K	Red/Red/Orange/Gold
	R,12,14, 15, 22	3	49.9 Ohm 1%	Yellow/White/White/Gold/Brn
	R16	1	1 Meg	Brown/Black/Green/Gold
	R13	1	100 ohms	Brown/Black/Brown/Gold
	R17	1	220 K	Red/Red/Yellow/Gold
	R10	0	NOT USED	
	L1 (looks like a resistor)	1	1 uhy RFC	Brown/ Black/ Gold/Gold
	D2	1	1N5817	Note polarity line, match with line on board.

Now the capacitors:

	Location	Qty	Value	Markings/Type
	C2,3,8,9,11	5	0.1 ufd	104 monolithic
	C5,6,7,12	4	22 pfd	22 NPO
	C4, C10	2	10 ufd /16V	Alum electrolytic NOTE: these two caps must be mounted laying flat to the board as shown in photo.

Toroid Transformer T1:

- Wind and mount T1.
- First wind 30 turns of #30 magnet wire on the black, FT37-42 core.
- Then wind an additional 5 turns in the space between the start and finish of the 30 turn winding.
- Trim and tin the wire ends.
- The 30 turn wire ends go into the two outside pads and the 5 turn winding wire ends go into the two inside holes.
- It's easy to mix these wire ends up, so be careful.



Remaining parts

	Location	Part	
	Q1, Q2	2N5179	Transistors TO-92
	U3	74HC4046 Note Board may have "74HC4042"	16 pin dip IC – DO NOT USE SOCKET – Using a socket here will affect tuning range and stability of oscillator.
	U1	74HC4017	16 pin DIP IC – Socket can be used if desired
	U2	20 pin IC socket – check for any leads bent over and not sticking through pads before soldering.	Insert Tiny2313 chip into socket after remaining parts on board are installed.
	Display	4 digit LED display	Due to missing pins, this part can only go in one way.
	X1	10 MHz crystal (A100)	
	SW2/3	DPDT slide switches	Make sure switch body is flush and square to board before soldering more then one lead.
	D1	Clear LED T1 (3mm) size	Short leg goes into hole next to flat side of part outline. To get the spacing correct from the board, mount board with LED into case before soldering leads. (Top of LED lens will be about 13/32" from top of board).
	SW1	TACT push button switch	
	V1	9 mm, 10 K potentiometer.	

Installing U2:
You can now install U2, the TINY2313 into the socket.

Power:
Wire the battery holder or other power supply of 6-14V to the board, red wire to the '+' pad and black wire to the '-' pad.

Testing:

Make sure the on/off switch is in the off position (slide to left).

Connect up a power source, 6 to 14 volts. A 9V radio battery or four “AA” cells will do.

Turn unit ON with the on/off switch.

The frequency display should light up, showing all 8's and decimal points lit for a couple of seconds.

This indicates all the segments are working.

Then the current frequency will be displayed, in MHz. [xx.xx] MHz The SWR indication LED should be fully bright.

Now check the tuning range of the oscillator by adjusting V2 and the range switch, SW2.

Exact tuning range is dependent on component tolerances.

Low range: About 3.0 MHz to 11.7 MHz
High range: About 11.0 MHz to 30 MHz (note SWR LED will dim slightly above 27 MHz.)

Clicking the display shift switch, SW1, will make the display change from showing the frequency in MHz with 10 kHz resolution to displaying the frequency in kHz, with 100 Hz resolution.

This is indicated by the decimal point shifting from between the 2nd and 3rd digit to between the 3rd and 4th digit.

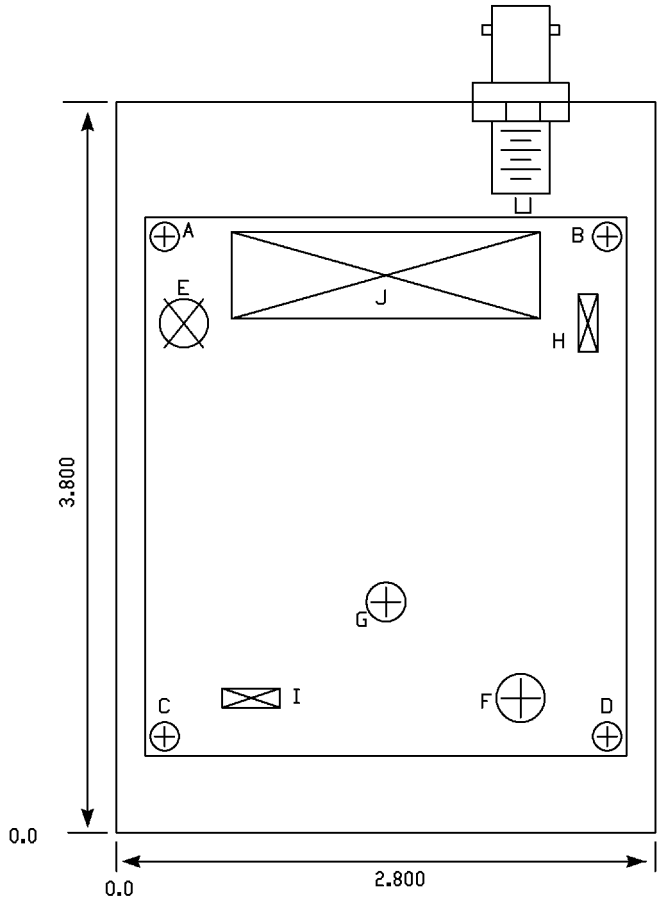
In the kHz display range, you will see the R/C oscillator isn't real stable, as the 100 Hz digit will be jumping around. This is normal.

Now test the operation of the SWR bridge by placing the left over 49.9 ohm resistor across the ANT pads.

The SWR LED should go out.

If the board passed all these tests, it is now fully functional and can be mounted in a case.

Front panel hole locations.

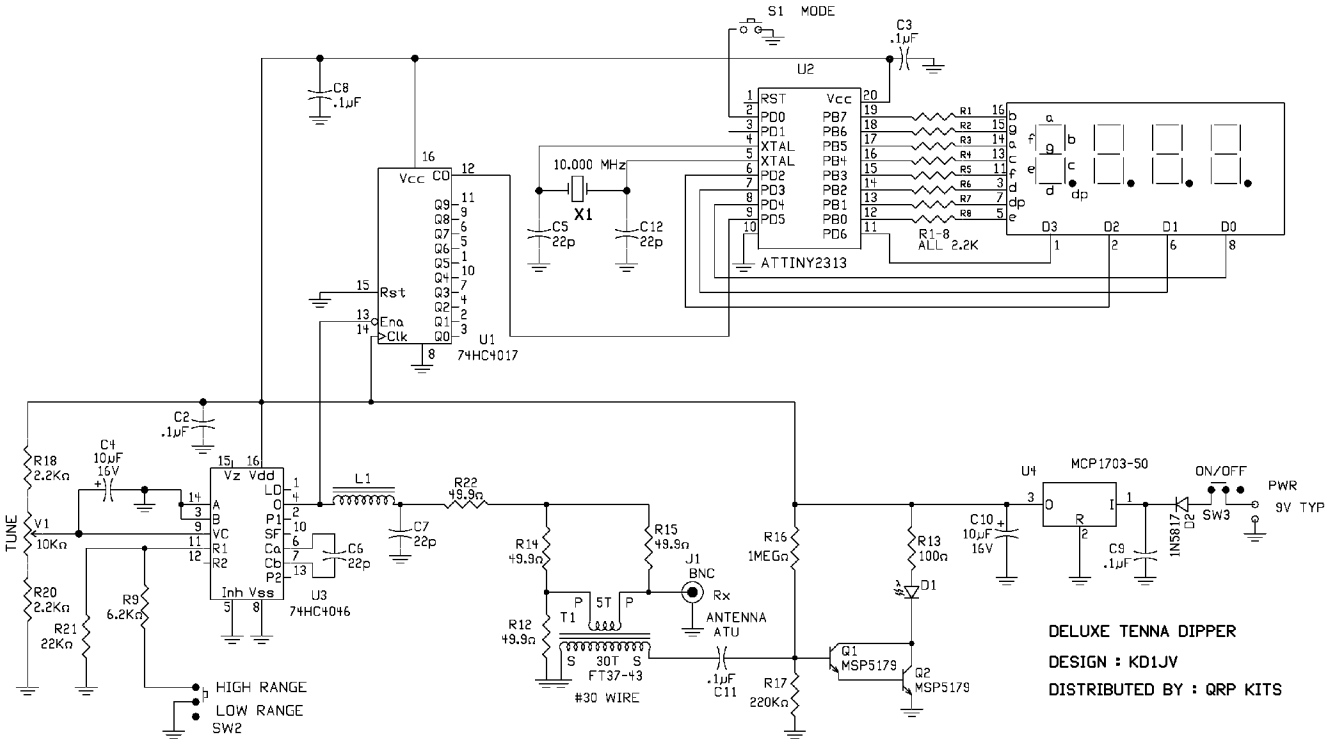


FRONT PANEL HOLE LOCATIONS

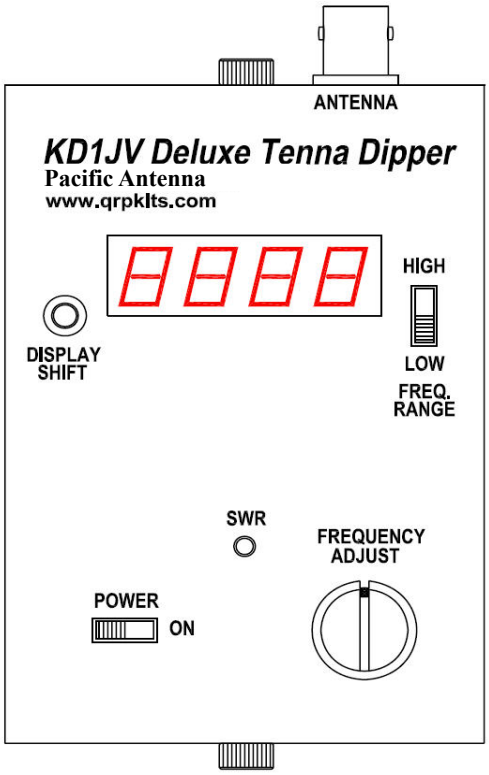
This page should print to scale and can be used as a drill template. The dimensional chart hole locations are referenced to the 0.000/0.000 location of the overall panel.

HOLE	SIZE	X	Y
A	#4 PEM 0.325"	0.500	3.100
B	#4 PEM	2.550	3.100
C	#4 PEM	0.250	0.500
D	#4 PEM	2.550	0.500
E	0.25" dia	0.350	2.650
F	0.500"	2.100	0.700
G	0.125"	1.400	1.220
H	0.160 X 0.350 (XY)	2.450	2.650
I	0.350 X 0.160	0.700	0.700
J	1.600 X 0.500	1.400	2.900

Schematic:



Decal layout:



DIY Audio Home

307A push-pull amp

I've been playing with the 307A directly heated pentode for a while now. It's really one of my favorite tubes. I designed and build a (expensive) single-ended tube headphone amp using it, the TTVJ Millett 307A.



I've been breadboarding various SE and PP power amp circuits with the 307A for a good year or more, but just haven't had the time until now to come up with anything I like.

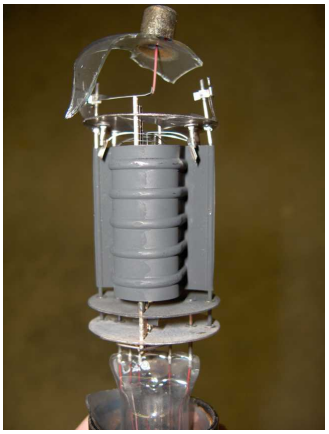
But first, a little about the 307A:

As far as I can tell, the 307A was only used in a WWII US army field radio. Even though the only datasheet I can find is from Western Electric, I've never actually seen a WE branded 307A (and I have a pretty good collection of them). I have 307A's from Ken-Rad (the most common), and Sylvania, Raytheon (AKA RK-75), and National Union. At least in the pictures the WE tube looks exactly like the Sylvania tube, so I'm guessing that WE may have just re-branded Sylvania tubes (or vice-versa).

Below are a series of photos of a Ken-Rad 307A tube in various stages of dismemberment. Click on the photos for full-sized images.

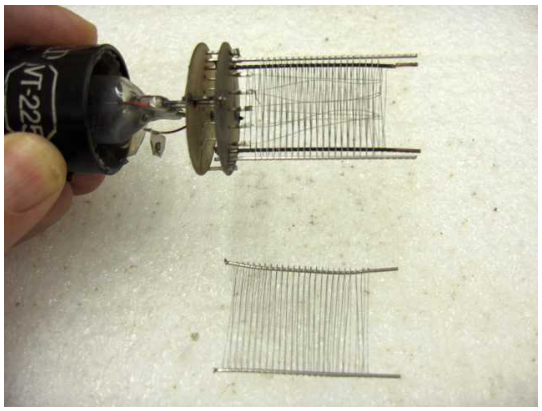


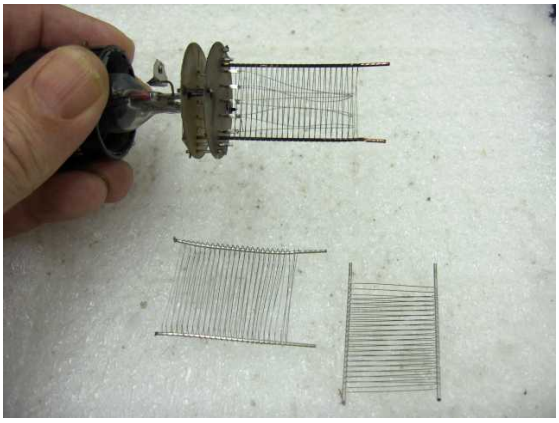










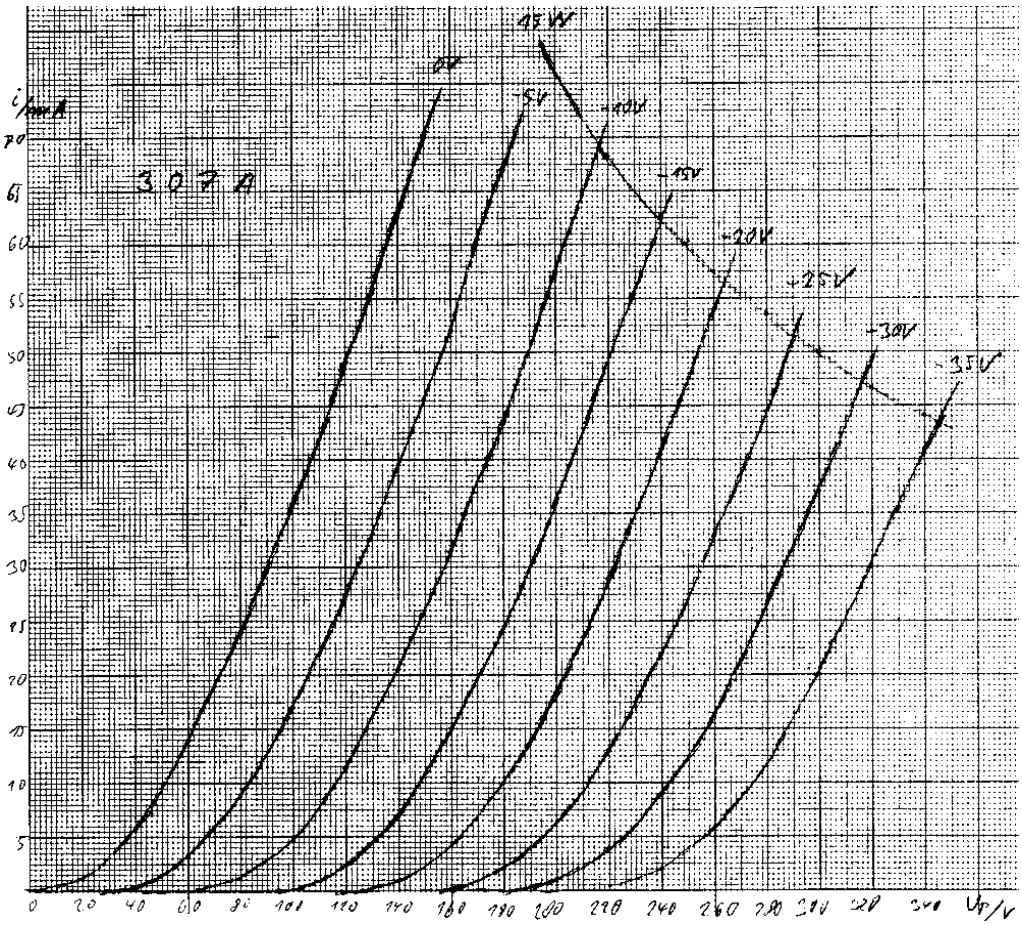



This is an old-fashioned pentode. No beam plates here... concentrically wound grids and an oval plate.

Finding 307A's can be a bit of a challenge. My stock came from England. I believe that most of the spares wound up in Europe since this is where the radio was deployed in the war. There are small quantities available at US tube dealers, and I know of at least one guy in Europe who seems to have a big stash.

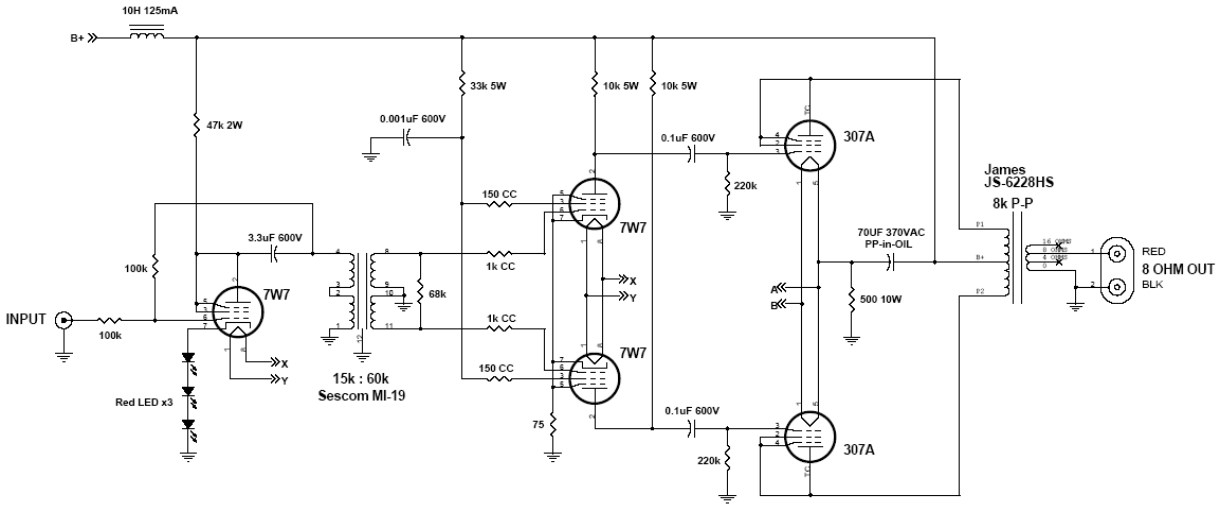
Anyway, back to amplifiers... I have run the 307A in pentode, ultralinear, and triode mode. I have not been impressed with pentode or UL operation - it works fine but nothing to write home about. But triode connected - in this case by connection G2 AND G3 to the plate - you get a very nice triode, somewhere between a 2A3 and a 300B in characteristics.

I found some triode curves somewhere on the net. I'd like to credit whoever made these but I cannot figure out where they came from - if it was you, please let me know so I can ask permission (and forgiveness) to post it!



The plate dissipation rating is 10 watts, but that seems to be a very conservative rating. I've been running them right at or slightly above that point for some time with no problems.

Here is the circuit that I am currently breadboarding (for a more readable schematic download the PDF version here).



ONE CHANNEL SHOWN,
OTHER CHANNEL IDENTICAL

307A Push-Pull Amp
2008 Pete Millett

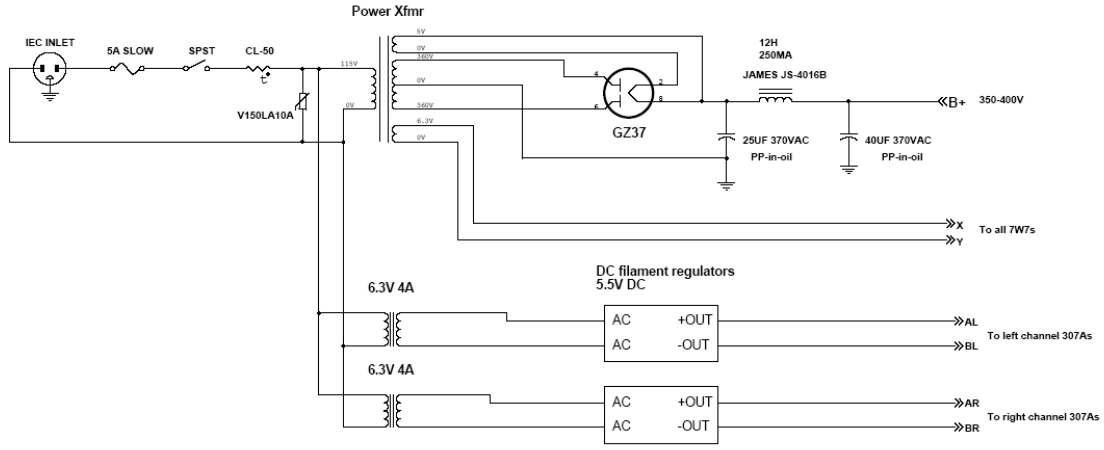
This design is pretty conventional. An input buffer drives a phase splitter transformer (I'm using a Sescom MI-19, which performs very well). A differential driver stage using 7W7 loktal pentodes drives the 307A grids via coupling capacitors. The 7W7 is a relatively unknown (until now?) jewel. I got a couple dozen for $1.00 each at RES!

A couple of oddities you might notice: The B+ is fed through a choke, and a capacitor (call it ultrapath or whatever you'd like) connected to the filament end of the cathode bias resistor. This B+ is used to feed the driver stages with no decoupling. So basically from an AC standpoint everything is tied to the 307A filaments. I found experimentally that this scheme resulted in significantly lower distortion than other connections. I believe that what's happening is that the B+ is being modulated with common-mode signal which tends to force balance in the entire circuit.

Another oddity is that the driver stage - a diff pair of 7W7 pentodes - share a common screen grid dropping resistor, and a very small (0.001uF) bypass capacitor. Again, experimentally, this worked considerably better than the usual choices, including a VR tube to regulate the screen supply, and separate screen dropping resistors, and using large bypass capacitor(s). Interestingly, using a big bypass cap increased THD significantly across the board. Adding a small cap lowered THD at high frequencies (above ~10kHz) without increasing distortion at low frequency.

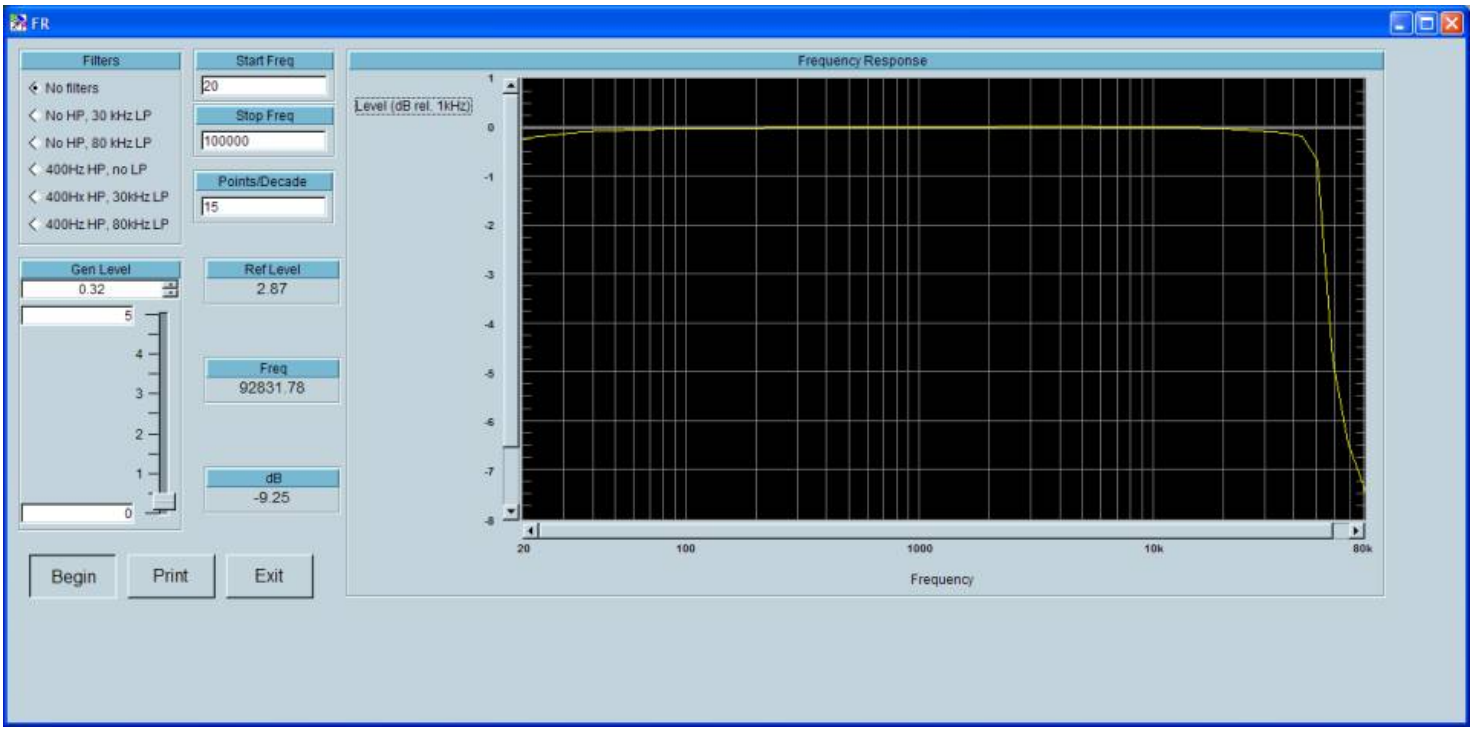
The input stage uses a triode-connected 7W7 in a near-unity-gain plate follower configuration. I did this to remove any dependencies on the driving source impedance - the frequency response and THD at high frequency is very dependent on how you drive the phase splitter transformer. With the buffer, the input is high impedance (100k) and resistive, so the source impedance doesn't affect the amp performance. Almost any triode will work - a 6SN7 / 6J5 / 7N7 / 7A4 works fine, but the higher Gm of the 7W7 makes for incredibly flat frequency response.

Here is the power supply, which is entirely conventional:

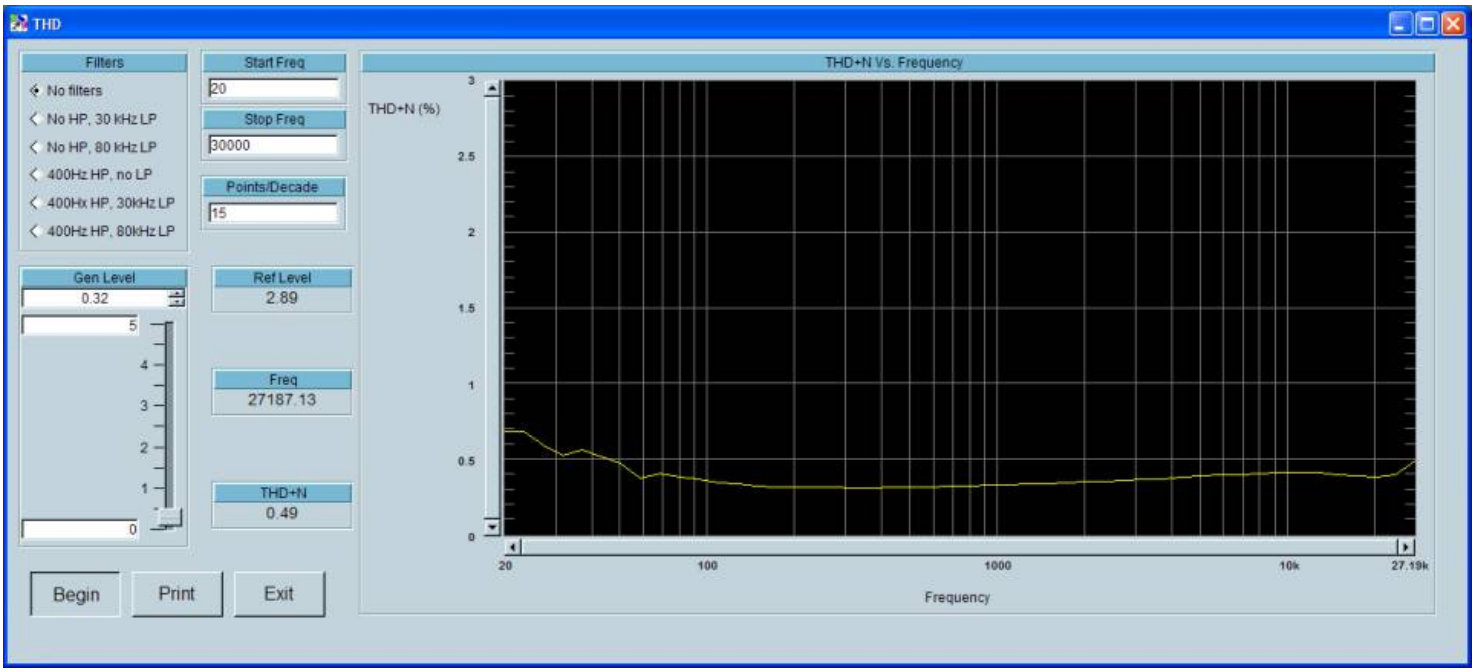


You can drive the 307A filaments with AC - with a hum balance pot you can probably get it quiet enough. But even with this I measured lots of hum intermodulation, so I opted to go with DC filaments.

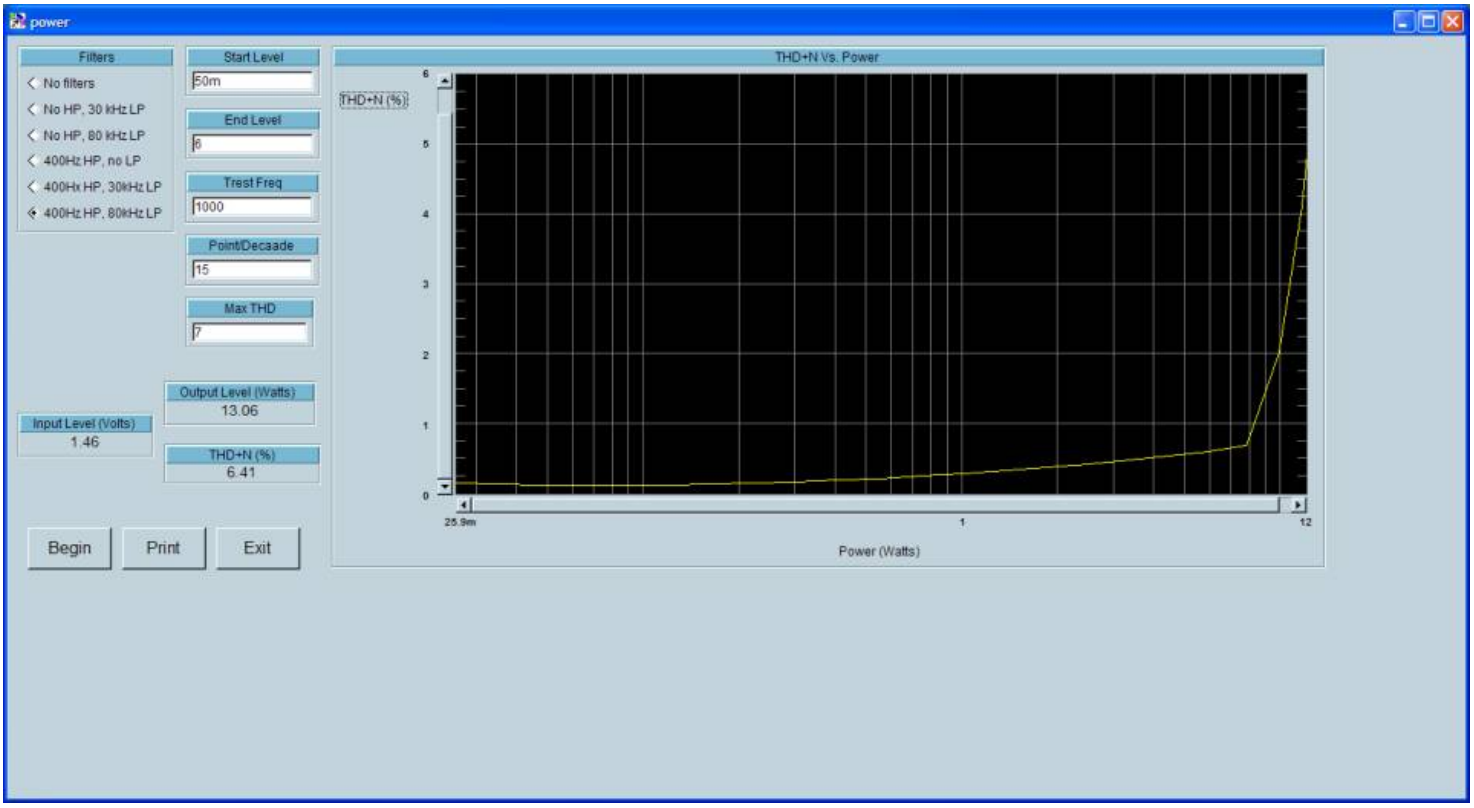
The performance of this amp is pretty impressive. Check out the frequency response (@ 1 watt out)...



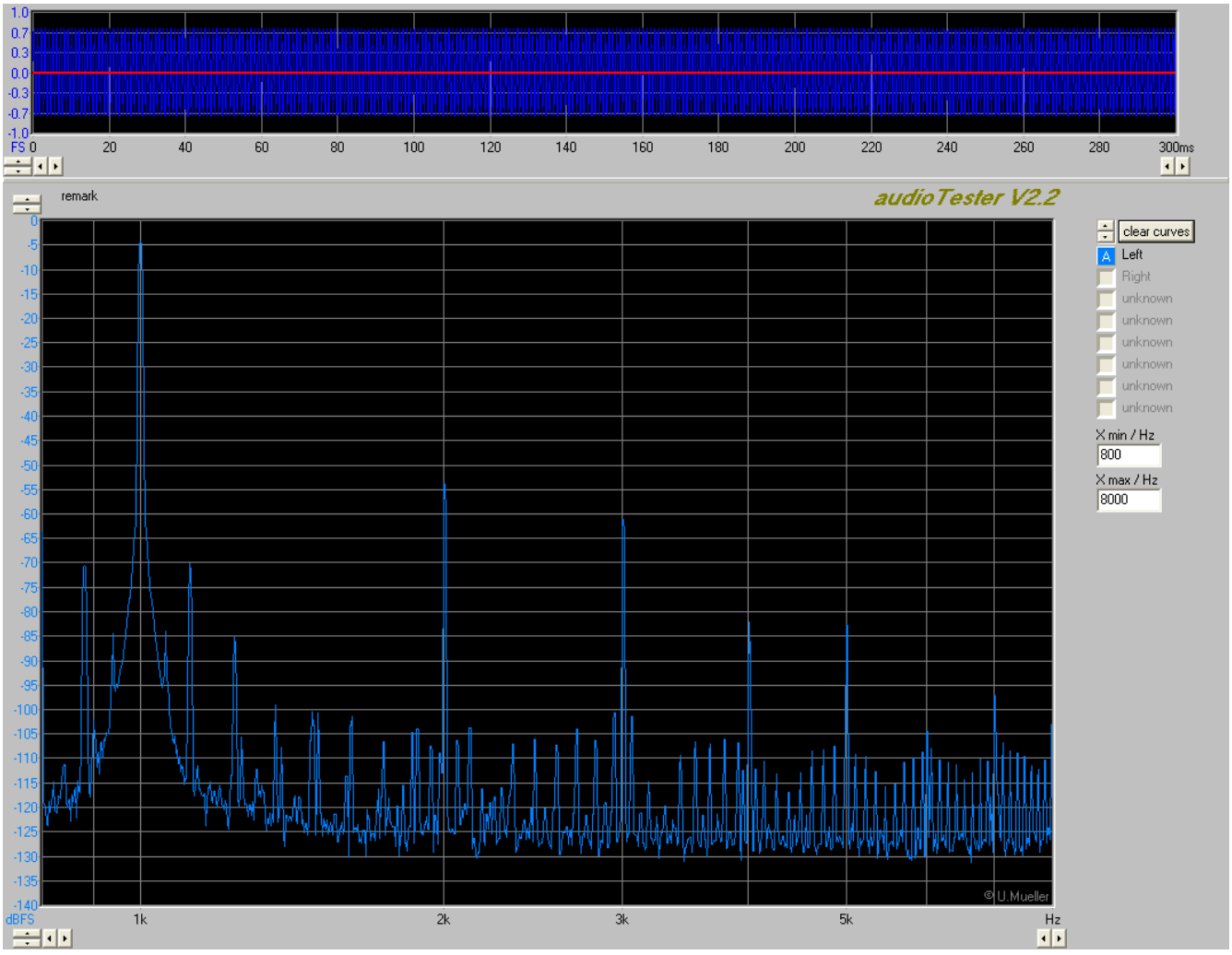
...the THD+N vs. Frequency at 1W out...



...and the THD+N vs. output power (@1kHz):



An FFT @ 1 watt shows a mix of distortion products Note there are still 60Hz products (albeit 70dB down). Not sure where this is coming from - DC on the7W7 heaters made no difference. This was powered from a regulated bench supply so I don't think it is B+ ripple. Maybe just a measurement artifact...

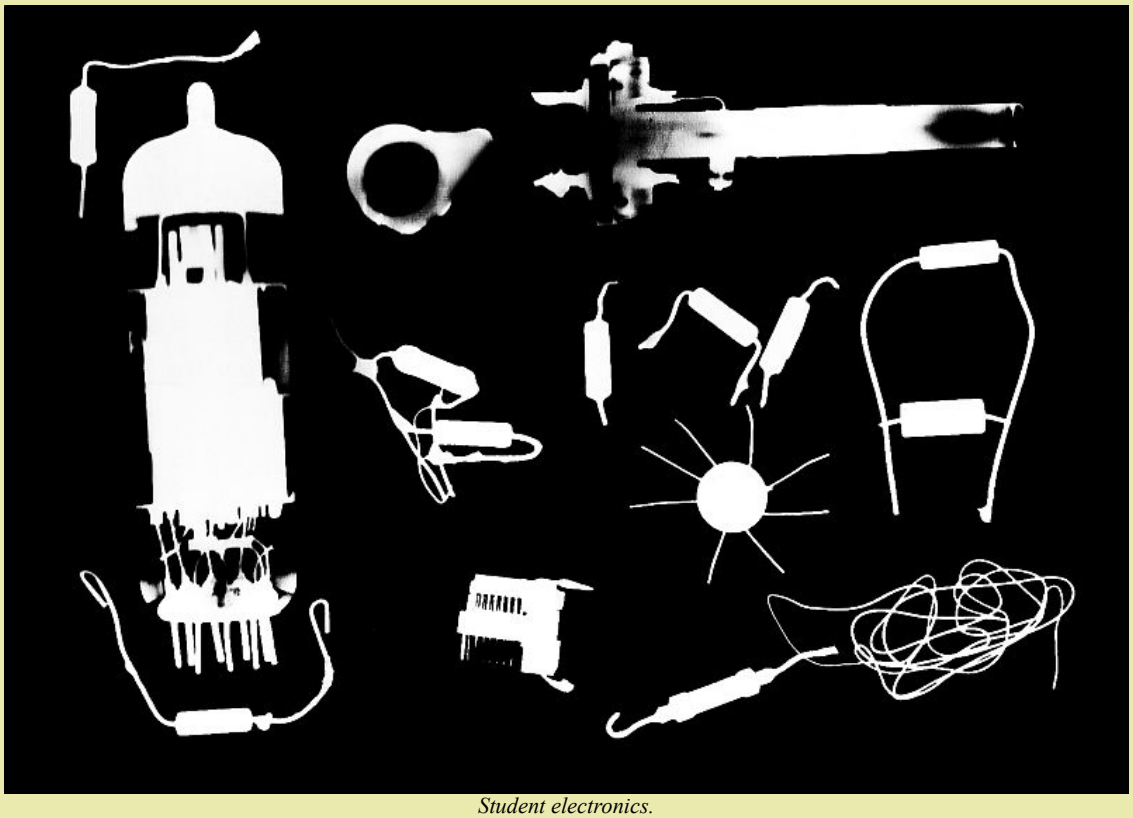


I haven't listened to this amp yet (I'm an engineer, damn it!). I do plan on building a proper stereo amp with this design, so listening will wait until then. More details to come then.

TUBE RECEIVER WITH EC92

(1973)

KLIK HIER VOOR DE NEDERLANDSE VERSIE



Student electronics.

No Radio officer

Radio officer on board of a ship, that was what I wanted to become. Two passions, Radio and the Sea in one profession. But there was no future in that profession. So I became a poor student electronics in an attic room. Classmates wanted motorcycles and even cars, but I did not need that! Freedom, happiness and simplicity, on free Wednesday afternoons barefoot to Amsterdam! To buy cheap books about radio! The Waterlooplein market! At that time, old radio equipment was still sold. I enjoyed it to see, but did not want to have it. However, buying a beautiful coil or special crystals that had to be possible! Very simple with toe slippers or bare feet, even in the snow! What a great simple and carefree life, no money, no belongings, no worries about mortgages and pensions! Only a few minor problems such as that sometimes a glass splinter had to be removed from my bare feet...



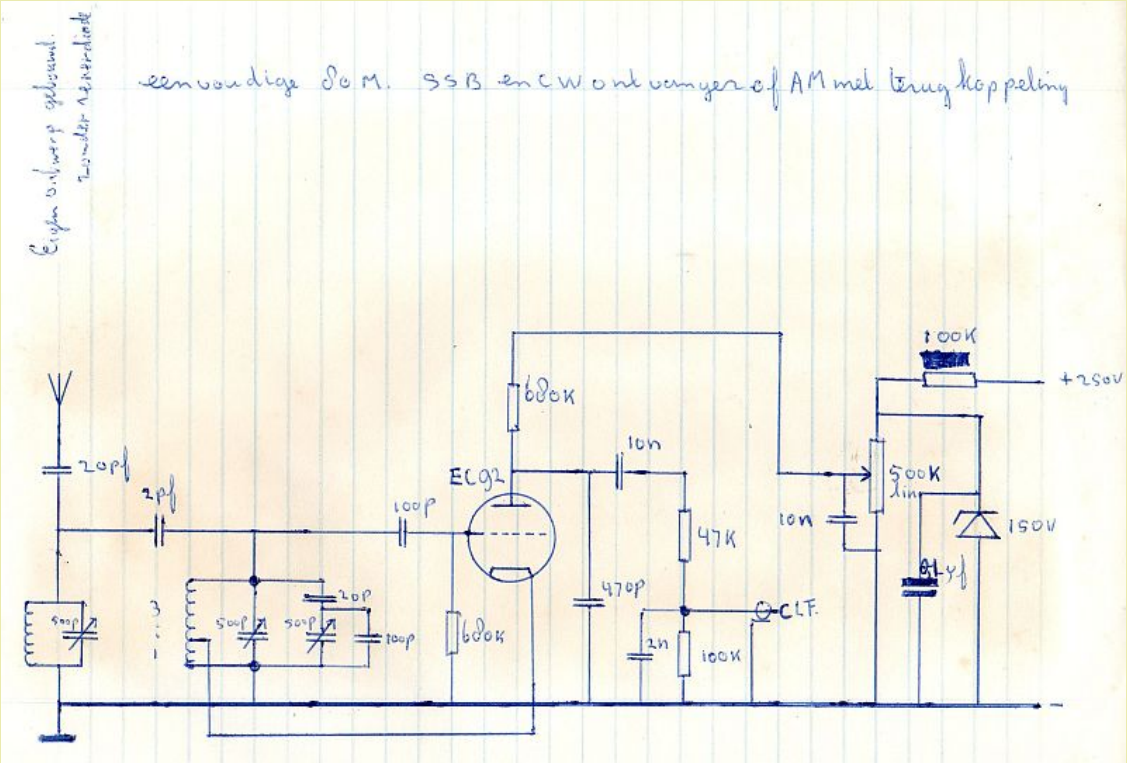


Barefoot to Amsterdam.
Then you had trains with real locomotives!

Some classmates were radio amateur. Friendly people who spend the whole day with talking about radio. They bought expensive two-meter transceivers and large, heavy shortwave receivers. But I wanted simplicity preferred to play with a crystal receiver. Listening to the shortwave broadcast stations during many hours was nice. Listening very simple to radio amateur with a simple regenerative receiver for 80 meters. With a tube, such as was used in the early days of radio! Indeed, I wanted to build such a receiver!

It had to be a receiver that easily would fit in a plastic bag to take it everywhere. There were still some parts and a EC92 tube left from experiments with illegal transmitters. It became a simple regenerative receiver with triode EC92 and a crystal phone. And with fine tuning. The control of the regenerationk was perfect.

You could adjust it right on the edge of generation. Or slightly over it for optimum reception of weak SSB stations. And oscillating quite strong for strong SSB stations. The real historical radio sensation. A wire of 5 m along the rafters of my hired student room as an antenna. And the bed was used as ground.



The regenerative receiver for Scheveningen radio and 80 meter.
The zenerdiode is drawn, but never mounted.

Description
Unfortunately, there is no picture of the receiver. But I do have the original drawing of the diagram! It is a 0V0, so ony a detector tube, no RF and LF amplifiers.

Tuning
Between the antenna and receiver an additional tuned circuit was added to suppress the audio breakthrough of strong broadcast stations just above 4 MHz and strong broadcast stations on the 2nd harmonic, the 7 MHz broadcast band. For the reception of SSB and CW, the receiver has to oscillate. And the second harmonic of the oscillator signal fell exactly in the 7 MHz band. After this addition, the reception was free of interferences. The antenna is connected with the top of this tuned circuit via a capacitor.
Then follows the tuned circuit. Via a very small capacitor, the first tuned circuit is connected to this tuned circuit. There are two tuning capacitors, one for the coarse tuning and one with a parallel and series capacitor for the fine tuning. Because of the parallel and series capacitors, the influence on the tuning of this second capacitor is much less.

Detector
After the tuned circuit you can find the triode. It detects the RF signals by means of grid detection, the grid-cathode space works as a diode. For the regeneration, the cathode is connected to a tap of the coil. The regeneration is controlled by lowering of the anode voltage by means of a potentiometer of 500k. It works excellent but it seems to me not really a good method. As not only the RF gain is reduced, but also the LF gain. And you want to keep the LF gain as high as possible!
The capacitor of 470pF at the anode is the decoupling of the RF signals to ground. The next capacitor of 10nF provides the separation of the DC voltage and AC signal. The resistor of 47k and the capacitor of 2nF are a low pass filter. And the resistor of 100k prevents that there is a DC voltage over the crystal phone.

Supply
A single phase rectifier and elco is used. It is not drawn. The planned voltage stabilizer by means of the zenerdiode of 150 volt is not used. The 100k resistor and 0.1uF capacitor are used. And of course, the 6.3 volt filament voltage from the transformer is connected to the tube and at one side to ground.

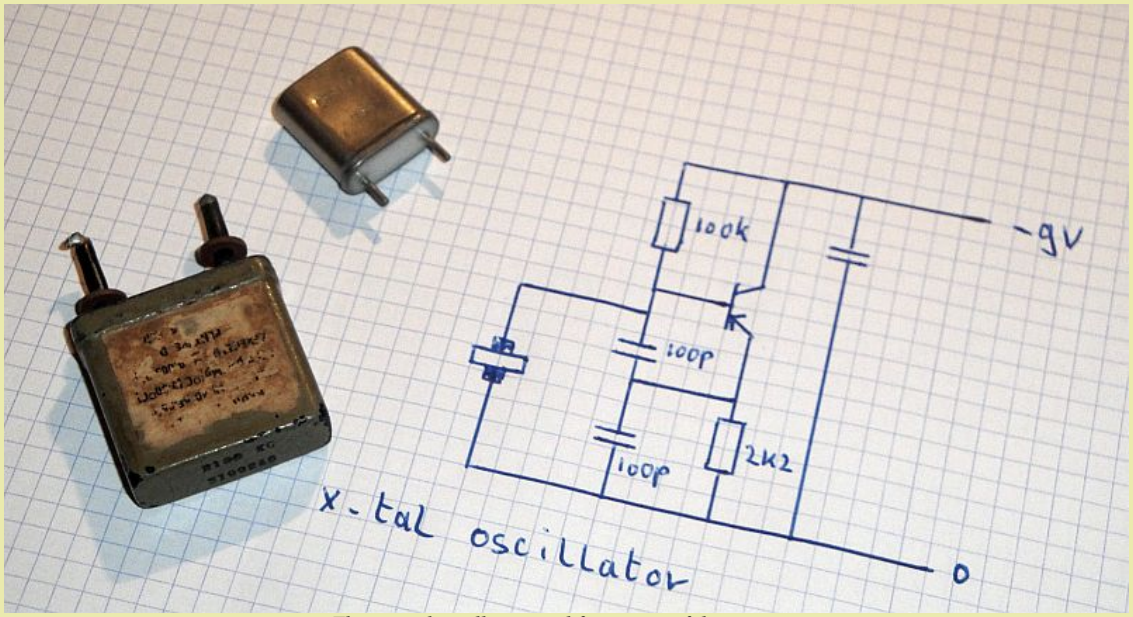


The tube EC92



Variable mica capacitors were used for the tuning.

Crystal oscillator to tune the receiver.
Again barefoot to Amsterdam to buy crystals on the Waterlooplein market. One with a frequency of 2182kHz for the emergency and calling frequency for the shipping. And one with a frequency of 3640kHz to find the 80 meter band, the Oldtimer net. I made an oscillator, it did not need an antenna, as it radiated already enough. With a 9 volt battery, the connection clip was mede of an old 9 volt battery and was also the on- off switch.



The crystal oscillator used for tuning of the receiver.
Two frequencies, 2182 kHz for shipping and 3640 kHz for the amateurband (Oldtimer net).

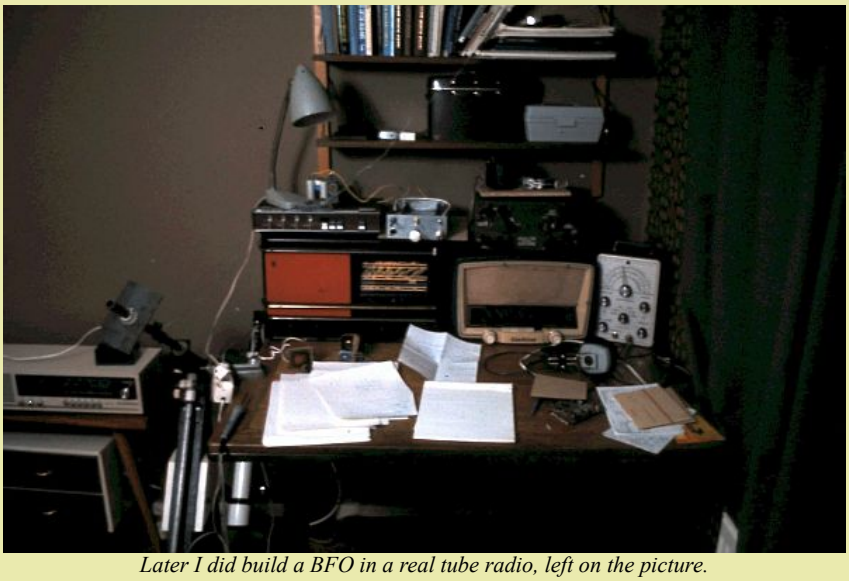
And then the 0V0 was ready!
Radio does not have to be expensive! The control of the tuning and regeneration was working with hands and feet and never boring. Listening to Scheveningen radio for radio traffic with ships and radio amateurs. Of the Dutch radio amateur net, most stations could be received. That Duch radio amateur net is still there, Scheveningen radio not anymore... Listening to the Night owls net. Amateurs who talk with each other late at night.
Often a radio amateur in my neighbourhood thought that someone was tuning on the frequency. But of course, wat he did hear was my beautiful oscillating receiver! At that time I did not know what you can do with low power! This receiver was built in 1973. I still know that because all amateurs said "Best 73" to each other. I had expected that after the turn of the year it would become "Best 74"! How much fun you can have with such a simple receiver. Listening during many hours in the winter with my bare feet on the cold linoleum of my students room!



My very nice student room!

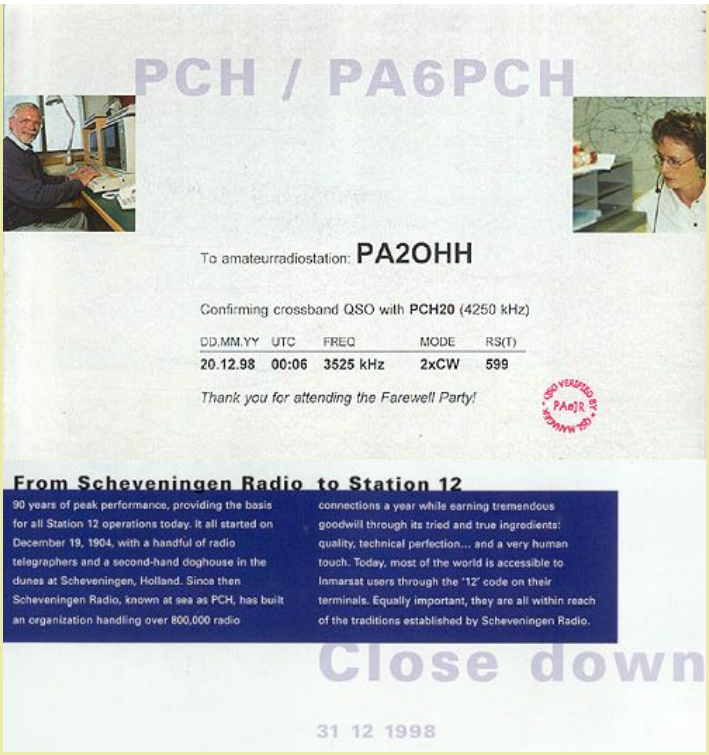


With real kitchen!



Later I did build a BFO in a real tube radio, left on the picture.

And radio officer?
I loved the sea! Walking on the beach from Zantvoort to IJmuiden. In the winter, because then the beach was so pleasantly deserted. There I stood with my bare feet in the cold water looking at huge ships that left the harbour and then I found it a pity that I could not become a radio officer anymore... Although,a radio operator wears polished shoes and certainly does not walk barefoot in Amsterdam of course! It might be that I was totally unsuitable for that job! That evening at home I listened to the ships with my 0V0. Not with polished shoes, but with my bare feet on the cold linoleum. And 25 years later the job of radio officer was History...



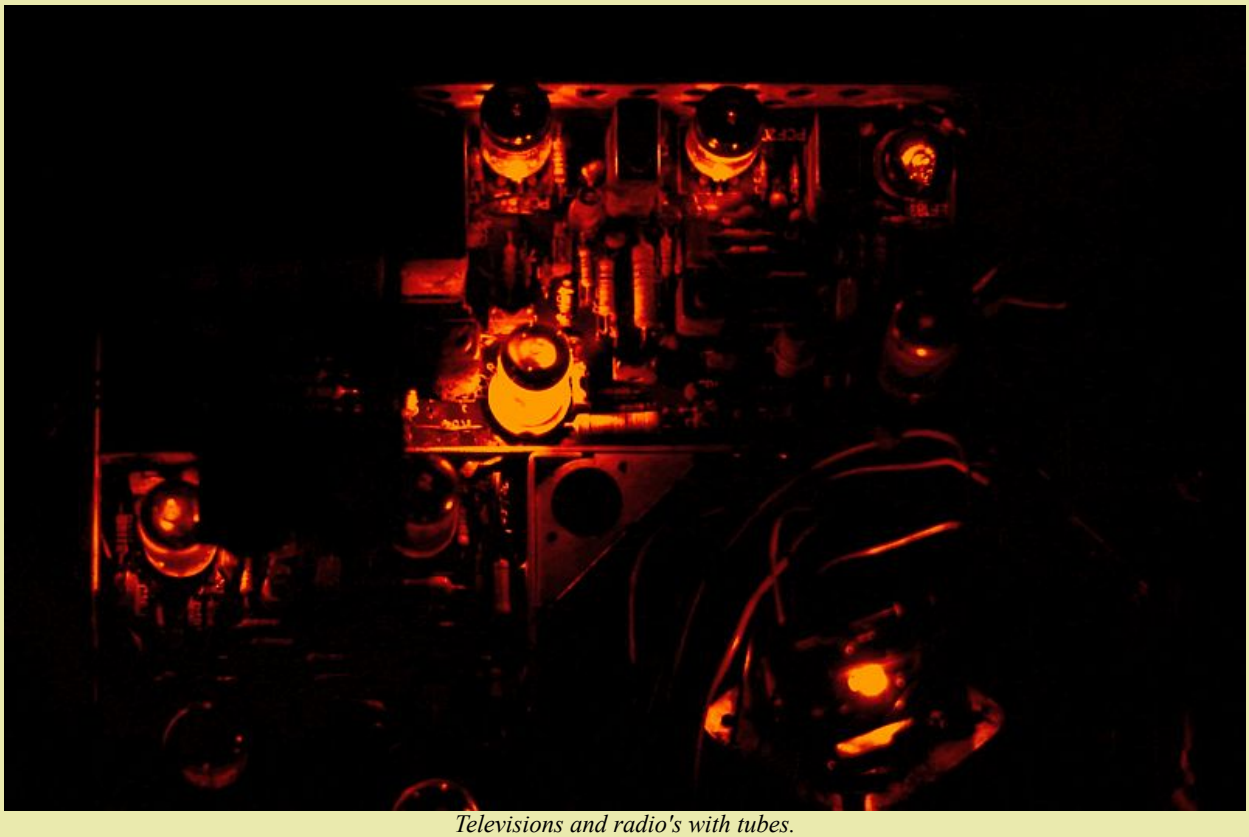
History!

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0V0 MEDIUM WAVE RECEIVER WITH A BATTERY TUBE

(1964)

KLIK HIER VOOR DE NEDERLANDSE VERSIE



Televisions and radio's with tubes.

Radio!
All those beautiful parts and then finally the sound of a self-built radio, fantastic! I had made already a transistor radio, but now a radio with a tube had to be made! Radio electronics was my hobby! In the attic was the table where I was allowed to solder. Cutted wires from electronic parts in my socks, I was already totally used to it!

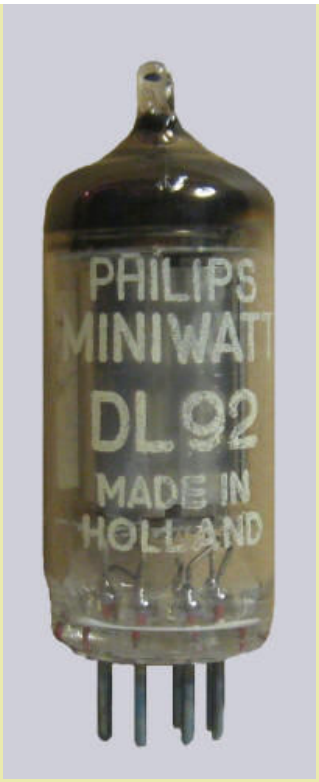


We played in unheated bedrooms. With ice on the windows as double glazing did not exist and only living rooms were heated!

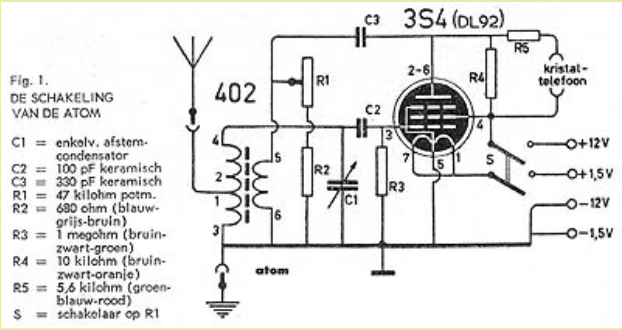


And we had real winters with much snow and ice!

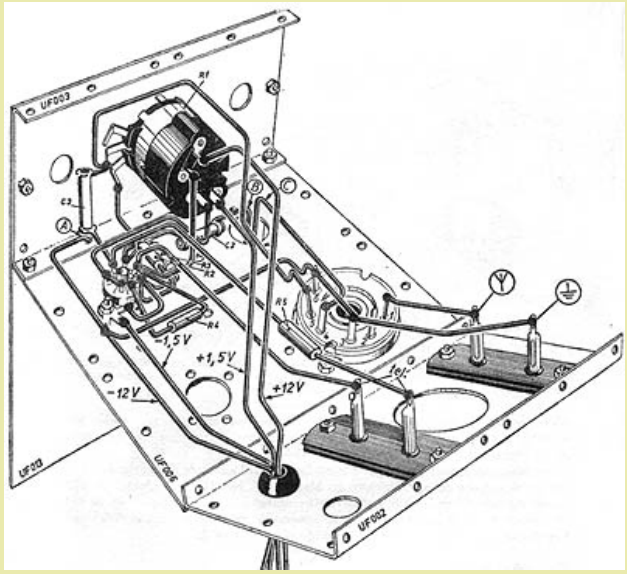
And it was cold, we had real winters! Only living rooms were heated. So we played in unheated ice cold bedrooms. With ice on the windows as double glazing did not exist! But we have survived the harsh winter of 1963 without any problems! At that time, we were not dependent on electricity. If there was a power failure, we simply took a candle, the fire kept burning. And we did not have a fridge, we had a basement. And every evening, the water was cut off to prevent frozen water pipes.
We played with Lego, Meccano, cars and electric trains. And sometimes we were allowed to play with the radio at Peter's home! Those morse stations on the longwave, looking at those tubes, great! I got a book about radio and of course I had to build a radio with a tube!



The applied tube DL92.



The ATOM receiver was my first radio with tubes. It was a small 7 pin tube for use with batteries. The anode voltage was 13.5V (3 flat batteries in series) and the glow wire voltage came from a fat 1.5V battery.



The tube radio "ATOM" from the book "Boys Radio" was built.
The ATOM receiver was my first tube radio. With a small 7 pin battery tube. It is a 0V0, so only a detector tube and no RF amplifier and no LF amplifier. The construction consisted of Amroh aluminum chassis parts. And the very well-known 402 coil was used, with which the whole medium wave could be received. For the tuning I used such a well known "brown" mica variable capacitor.
For an optimal match, the antenna is connected to a tap of the coil. The tube is connected to the top of the tuned circuit. Grid detection is used, the grid-cathode space acts as a detector. The grid can also receive a negative bias due to the grid current that always flows when the cathode-grid voltage is close to 0 volts. Here it is a little difficult because of the voltage that is caused by the filament voltage. Different parts of the cathode have different voltages.
The tube does not only amplify the detected low-frequency signal, but also the high-frequency signal. From the anode, a part of the amplified high-frequency signal is fed back to pin 5 and 6 of the coil 402. By means of the potentiometer R1, the part of the RF signal that flows via the coil or via the potentiometer can be adjusted. And that is how the regeneration control works. For amplitude modulation it has to be set to the level that it does just not generate. Via R5 (probably a blockade for the high-frequency signal), the detected low-frequency signal by the tube flows to the crystal phone.
Unfortunately, the adjustment of the regeneration was not really good. You could not set it to the level that it just started to generate, because the receiver began suddenly to oscillate. But it had still a good medium wave reception. Maybe I just needed to change the polarity of the filament, at that time, I did not have the idea to try that out.
Early in the morning with my bare feet on the ice cold linoleum I was listening to the extended weather forecast and the prices of vegetables. Great when you hear that with your own receiver! With the curtain rail as an antenna and the bed as earth. And in the evening there were many

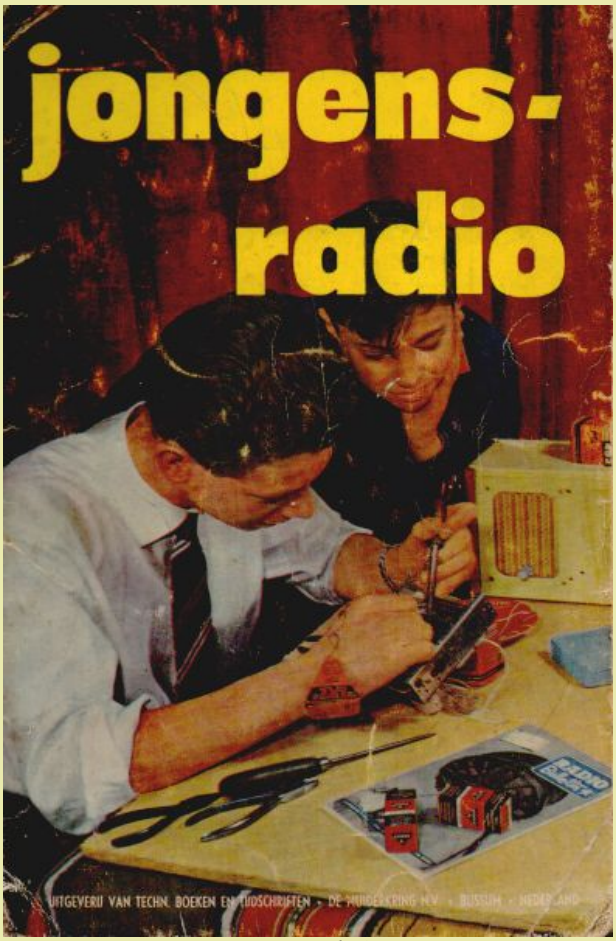
foreign broadcast stations! That fading, wonderful!
Cold red toes, during many hours I was listening to all those medium wave transmitters. But that battery for the filament voltage, what was that quickly empty! A considerable drain on my pocket money! Unfortunately, I did not use this receiver very long. Accidentally I reversed the 1.5V battery and the 12V battery connections. A very short flash inside the tube and it was dead. I did not have money for a new one...



The famous Amroh mucore-402 coil wass used in this design.
(Picture from the website of Piet Blaas)



The anode voltage was 13.5V (3 flat batteries in series).



Boys Radio!
I did read in this book during many hours!
The design of this receiver was found in this book.

Life was simple.
Life was simple. Almost everyone had a radio with tubes tuned to the medium wave. Many also had a black and white television with tubes and

only two channels, Netherlands 1 and Netherlands 2. On Wednesday and Saturday afternoon we were allowed to watch television. A program of one hour for children. And some had a record player. All those glowing tubes were wonderful to see! You had to pay tax for the use of a radio and television, unthinkable nowadays!



Almost everybody had a radio with tubes.

BACK TO INDEX PA2OHH

How to Terminate Coaxial Cable

Reader Approved

Coaxial cable can be used to transmit a variety of signals, including cable television, internet and low quality audio. If you're working on a project that falls in any of these categories, you can make your own cables and save money by learning how to terminate coaxial cable yourself.

Steps

1 **Gather your materials.** In order to terminate a coaxial cable, you will need the following tools and materials:[1]

- Coax compression connector - There are several types of connectors available. Compression connectors provide the best connection and finish to your cable. The second-best type of connectors are "crimp" connectors. Avoid push-on or twist connectors.
- Compression/crimping tool - Make sure it is compatible with the compression/crimping connector.
- Coax cable stripper tool
- Cable cutters
- Connector installation tool - This tool is used for pushing the connector firmly onto the stripped cable.

2 **Make a straight cut at the end of the cable.** Use your cutting tool to make a straight cut at the end of the cable. After cutting, use your fingers to form the end of a cable back into a circle.

3 **Adjust your stripper to work with your cable.** Most coaxial strippers can be adjusted to strip dual-shielded or quad-shielded coaxial cables. Use the included Allen wrench to adjust the stripper. If you don't adjust the stripper properly, you may strip the ground wire, damaging the cable.

- The most common cable is RG-6, either quad- or dual-shielded. Make sure that the stripper is configured for RG-6 coaxial cable, and not another cable size such as Ethernet cable.
- If your stripper is set to dual-shielding, but you try to strip a quad-shielded cable, not all of the shielding will be removed.

4 **Strip the end of the coax cable.** Place the end of the coax cable into the stripper so that the end of the cable is flush with the far end of the stripper. Clamp the stripper down on the cable and spin it around the cable two to three times.

- You can tell when the stripper is finished when you don't feel resistance anymore when spinning.
- Don't pull the stripper off when finished. Unlatch it and open it to remove the cable.

5 **Pull off the outer shield.** After stripping the cable, you should see two segment cuts. Pull the outermost segment off of the cable. This should reveal the center conductor wire.

6 **Pull off the second segment.** This will reveal the foil that insulates the cable. Find the edge of the foil and peel it off the cable. This should leave a single layer of foil around the white insulation.

7 **Fold back the braid.** When you pull off the cable jacket, you will see a lot of loose ground wires. Fold these back against the cable so that the connector will be touching all of the wires when installed. None of the wires should be blocking the white insulation.

8 **Cut the conductor wire (if necessary).** Most cable stripper tools will leave the correct length of conductor wire exposed, but it doesn't hurt to double check before proceeding. The exposed connector cable should be 3.9 mm (.156 inches) in length.

9 **Put the connector onto the stripped end of the cable.** Use a pusher tool to firmly push the connector onto the cable until the white insulation is flush with the connector.

- Make sure you avoid bending the bare conductor wire when installing the connector.
- You may need to twist the cable while pushing with the tool to get it firmly connected.

10 **Compress or crimp the connector.** The process for compressing or crimping the connector varies depending on the type of connector you are using. Some require you to press down on the cable-end of the connector piece, while others require you to push the front and end of the connector piece into each other.

- Squeeze the compression or crimping tool firmly. Most tools won't allow you to over-compress, but some can cause damage to the cable and connector if compressed too much.

11 **Inspect the connection for imperfections.** After you have finished compressing the connector, inspect it for any stray wires or loose connections. These can lead to a bad signal or nonfunctional cable.

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Tips

- Once you have adjusted the stripping tool for the brand of cable you are using, it won't strip other brands of cable properly without readjustment. Use one brand of cable for your whole project.
- There are several different types of coaxial cable and connectors. A few of the more commonly used are ADC DSX-CM-1000, WECO Type 734A, Belden YR23922, Belden 1505A and GEPCO VPM2000. The most commonly used coaxial connectors are BNC-734 and TNC-734.
- If the coaxial cable has a foil shield underneath the braided shield, you want it cut to the same dimensions as the braided shield.

Sources and Citations

1. http://www.datacomtools.com/catalog/ideal/How-to-terminate-coax.htm

Frequency counter / Digital Dial

The Digital Dial is primarily intended to be used as a simple means of adding a digital frequency read out to single band QRP radios. A programmable IF offset feature allows the counter to measure the VFO frequency but display the actual operating frequency. The digital dial can also be used as a general purpose frequency counter. It also includes a special “crystal matching” mode, which allows the matching of crystals used in IF filters to with in 10 Hz of each other.

Specifications:

Frequency range: 100 kHz to 45 MHz
Resolution: 100 Hz displayed, 50 Hz internal
Update rate: 200 ms
Input level: 50 mv to 100 mv p-p min, 2 V p-p max. (sensitivity varies with freq)
Input impedance: 1 Meg ohm.
Display, four digit LED
Supply voltage: 8 V min, 14 V max
Supply current: 37 ma, typical
Size: 2.1” wide, 1.1” high, 0.5” deep

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Manual updated 6/8/11

Assembly:

Empty the contents of the static bag into a soup or cereal bowel. This will help keep you from losing any of the small parts.

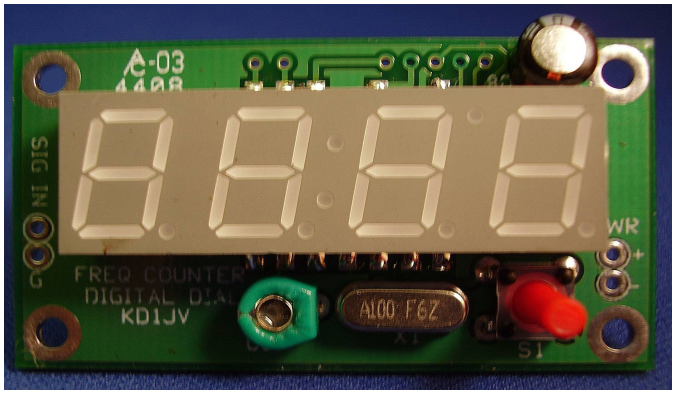
In order to make identifying the SMT parts easier, some of the parts have been color coded. The colors indicated on the layout diagram corresponds to the color marked on the SMT carrier package.

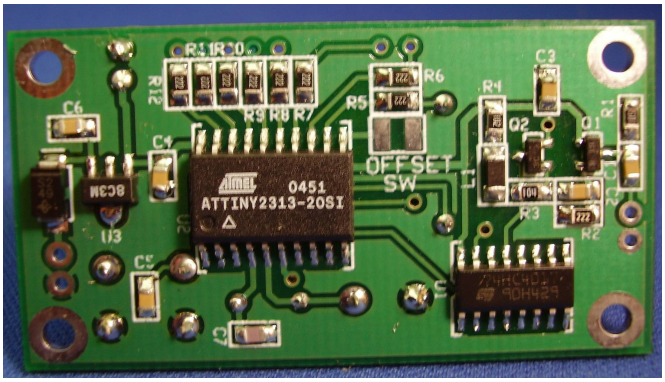
So that you do not mix up the parts, work with only one type of parts at a time. If there is more than one value used, place all of them before moving onto another.

Surface mounted parts are installed first. All of these go on the back side of the board. If this is the first time you've assembled anything using SMT parts, please refer to the “Building with SMT parts” appendix at the end of the manual.

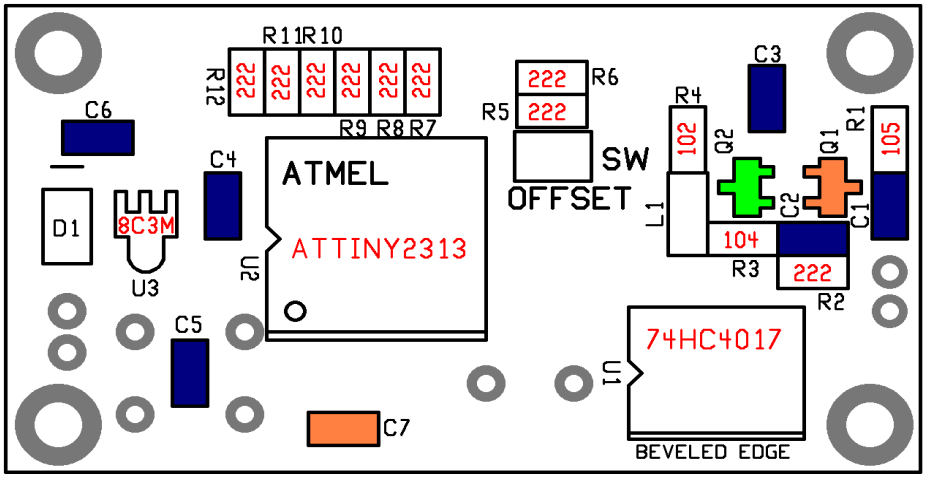
Solder: Do not use your usual solder, which is often 0.032” in diameter. Get some 0.020” solder, silver bearing is best. Radio Shack sell small rolls of this kind of solder.

Use these pictures to help locate and identify parts. Zoom in with the magnifier in the pdf viewer for a closer look.





Assembly: Back side

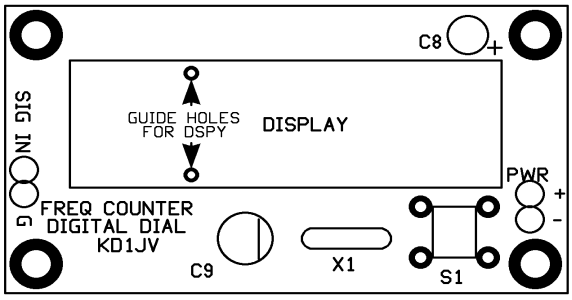


Recommended parts placement order shown in table:

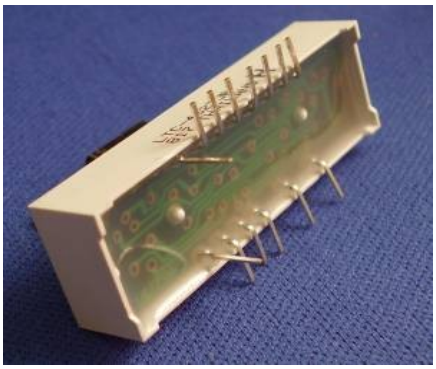
Note: Avoid pushing leads on Q1 and Q2 sideways when soldering, or it can damage the internal connections. Note beveled edge on U1 for proper orientation . Part number will also be in same orientation as shown in diagram. Note white line on D1 package, which will face towards the line above the D1 outline in diagram above.

√	*color*	*location*	*markings*	*type*	*quantity*
	ORANGE	Q1	6T N	.j-fet	1
	GREEN	Q2	3C f	NPN	1
	BLUE	C1 to 6	None, tan	0.1 uFd cap	6
	ORANGE	C7	None, tan	22 pFd cap	1
		R2 - R5 to 12	222	2.2K Ω	9
		R1	105	1 Meg	1
		R3	104	100K	1
		R4	102	1K	1
		L1	None, black	4.7 uHy	1
	----------	D1	S2 49	Diode	1
	----------	U1	74HC4017	counter	1
	----------	U2	Tiny2313	MPU	1
	----------	U3	8C3M	5V reg	1

Front side parts:



Display:



The display is soldered into place first. This requires a little rework before it can be done. All *but the two left most pins* need to be bent out at a 90º angle to the body as can be seen in the photo to the left. The part numbering on the side of the display indicates the bottom side, the side which will mount towards S1, X1 and C9. Simply fold the leads over with your thumb or needle noise pliers.

Once the leads are bent over, clip them back about half their length, so that the pins do not go beyond the edge of the pads on the board. Now the display can be soldered to the pads on the board. The two display leads which have not been bent to a right angle go into the two holes in the board as shown in the placement diagram above. This helps to ensures the display will be not end up crooked on the board. However, before soldering the pins in place, make sure it is parallel to the board and the corners of the display are flat to the board.

Once the display is soldered into place, proceed with the four remaining through hole parts.

C9	Green trimmer		
C8	47 uF/ 16V	Long lead +	
X1	10.00 MHz	crystal	
S1	TACT switch		

Note: the flat side of C9 mounts towards the line in the outline on the board.

Assembly of the counter is now complete. Now is a good time to inspect your workmanship and look for any solder connections you might have missed making. Look closely at both ends of the chip resistors and capacitors.

Test and calibration:

Connect up a power supply, a 9 V battery will do for now.
When power is applied, the display should light up with four eights and four decimal points for a couple of seconds. [8.8.8.8] This is the display test.

Once the display test is over, the counter will be in the kHz frequency counter mode. Due to stray pick up by the high impedance input, you will see random numbers flickering on the display. Short the [SIG IN] terminals and the display should now read all zeros. [000.0] Confirm Mode switch operation by clicking and verify display changes to MHz range [00.00] Clicking and holding close the Mode switch for one second should turn off the display. Clicking again turns the display back on.

Trouble shooting:

There isn't a whole lot which can go wrong with this board. If it does not work first time, there is a 99.999% chance the problem is with the soldering of parts. Therefore, this is what you need to look for first. The other .001% is a misplaced part.

Calibration:

The counter needs to be calibrated before it will measure accurately. This is done by adjusting the green trimmer on the front of the board. The trimmer has a range of about +/- 700 Hz at 10 MHz. The exact range is dependent on the frequency inputed to the counter. Higher frequencies will have a larger apparent range than lower ones. If no accurate frequency source is available for calibration, centering the trimmer cap in its adjustment range (45 degree turn from factory setting) will put it reasonably close.

An accurate signal source is required and should be done at the highest frequency available, which is in the range of the counter (45 MHz). For most of you, the most accurate signal source you may have available is your commercial “Big Rig”, and the highest frequency available will be in the 10 M band. In CW mode, most rigs transmit on the frequency indicated by the dial. You should of course, transmit into a dummy load. If the dummy load is well shielded, you might have to put a coax “T” connector in series with the cable going to the dummy load and add a short “antenna” wire to the tap. With a similar short antenna on the counter input, you will likely get enough signal to get a stable display on the counter. A more reliable method might be to use a resistor divider across the dummy load, say a 100 K in series with a 1 K resistor. The counter input would be connected across the 1 K resistor and the 100 K to the top of the dummy load. Start with as little power output from the rig as possible, then if needed, increase to get a stable reading on the counter.

Operation:

The digital dial is controlled by a single switch, which we will call the “Mode” switch. This switch may have more than one function, depending on the mode in which the digital dial is being used.

As a frequency counter:

The first time power is applied to the digital dial, it will power up in the frequency counter mode. Since the counter can count up to 45 MHz and there are only four digits of display, there is a “display shift” function.

On power up, the kHz and 100 Hz digits are displayed. This is indicated by the decimal point being to the right of the third digit. The most significant digit is indicating 100 kHz and the least significant digit is indicating 100 Hz, or .1 kHz.

To display the MHz digits, click the Mode switch.

The decimal point will now shit the the left one digit, so that it is to the right of the second digit. The display is now indicating 10's of MHz in the most significant digit and 10 kHz in the least significant digit.

Sleep Mode:

In order to reduce current consumption when the counter isn't being used, there is a Sleep Mode function. This turns off the display and powers down the MPU. The input circuits and counter are still under power, so current is reduced to only about 15 ma.

Activating Sleep Mode:

Click and hold the Mode switch for about one (1) second, until the display goes blank.

Waking up the display:

Click the Mode switch again to wake up the MPU and turn the display back on.

Using as a Digital Dial:

In most radios, an IF offset will need to be programmed into the counter in order to indicate the operating frequency of the rig. This is because the IF frequency is often a fractional MHz frequency, such as 4.91520 MHz. If the IF frequency has no fractional component, such as 9.000000 MHz, there is no real need to program an offset, provided one is only interested in reading the kHz part of the operating frequency.

There are three possible combinations of VFO and IF frequencies to obtain the operating frequency. These are:

1. VFO + IF = op freq
2. VFO - IF = op freq
3. IF - VFO = op freq

In the case of #1 and #2, the operating frequency increases as the VFO frequency increases. In the case of #3, the operating frequency increases as the VFO frequency decreases. All three of these cases can be handled by the counter, but you will need to know which combination of VFO and IF mixing your rig uses to program the correct mixing scheme into the counter.

The simplest way to get the IF frequency into the counter is to use the counter to measure the BFO frequency, so this is what we do. However, in a CW rig, the BFO frequency is typically set about 600 Hz higher than the operating or transmit frequency in order to hear the proper CW beat note. In some cases, the BFO will be on the low side of the transmit frequency, but this is rare. In SSB rigs, the BFO will be at the transmit frequency, as there is no offset for SSB reception.

If left uncorrected the BFO CW offset will result in the dial reading 600 Hz higher (or lower) than the transmit frequency. If the receiver has a BFO trimmer (and many do), you can use that to lower the BFO frequency by 600 Hz before programming the offset. This is easy enough to do, since you have the counter connected to the BFO anyway. After programming the offset, re-tune the BFO trimmer.

Programming the IF offset:

The first thing to do is connect the counter to your BFO oscillator. In some rigs, this will be a separate oscillator from the BFO mixer. (Such as 2N2xx rig builders) In many QRP rigs, the BFO oscillator is part of a SA612. In the case of a separate oscillator, connect the signal input to the counter to where the BFO feeds the BFO mixer. In the case of a rig using the SA612, connect the counter to pin 7 of the SA612 (or NE602, SA602) using the supplied 4.7 pfd cap in series with the cable going to the counter. This small capacitor will reduce loading on the oscillator so not to shift the frequency significantly or possibly causing the oscillator to stop working.

The counter should now be indicating the BFO frequency on the display. If it is reading all zeros, then your not getting enough signal and may have to use a larger coupling cap to the counter.

Entering the IF offset program mode:

The offset program mode is entered by momentarily shorting the two pads on the back of the counter board marked “OFFSET SW” This needs to be done only once, so you can just use a short piece of wire to tap a short across the pads.

Once the two pads marked “OFFSET SW” are shorted together, the display will change to indicate [LO - -]

The proper IF offset mode is then selected using the Mode switch on the front of the counter. Each time the switch is clicked, it will advance to the next mode. The display indicates these selections as such:

[LO - A] VFO + IF = op freq
[LO - b] VFO - IF = op freq
[LO - c] IF - VFO = op freq
[LO - o] clear offset from memory.

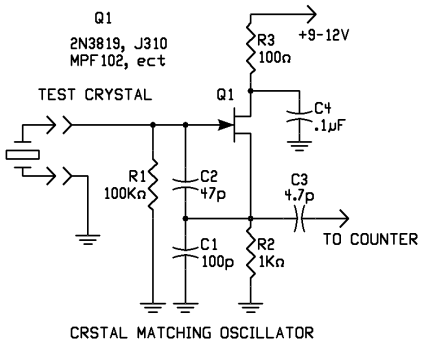
Once the proper selection has been made, click and hold closed the mode switch for one (1) second. If the clear offset was selected, the counter will go back to being a frequency counter. If selection “A” was made, IF+VFO, the frequency reading will be double what it was. If one of the other two modes were selected, the frequency reading will now be zero. If you adjusted the BFO trimmer, reset it now. You can now disconnect the counter from the BFO and connect it to your VFO.

Connecting the counter to the VFO:

The counter should be connected to the same point as which drives the receiver mixer. If the VFO is not buffered, try using the supplied 4.7p cap in series with the cable going to the counter, at the signal source. If there is enough signal level there to allow using this cap, it will reduce any possible loading effects of the connecting cable. Depending on the VFO frequency and output level, you might have to use a larger value coupling cap to get a stable reading on the counter. For short runs from the VFO to the counter, a twisted pair can be used. For longer runs, say more than 3-4 inches, shield cable, such as RG-174 coax should be used.

Display multiplexing noise on supply line.

Noise from the display multiplexing on the power supply line and then into the audio of a rig maybe possible. LED segment current has been reduce in this latest version of the DDial, as compared to earlier versions, which has significantly reduced the problem. If however, you do hear noise from the display, adding a series resistor (100 ohms to 220 ohms, depending on the supply voltage) and a filter cap at the board side of the series resistor (100 uFd or larger) will eliminate the problem. However, this will increase the minimum supply voltage requirement some.



CRSTAL MATCHING OSCILLATOR

Crystal Matching mode:

This mode allows you to match crystals to within 10 Hz of each other. By matching crystals closely, you can build very narrow CW ladder filters. You will of course, need a crystal oscillator to do this. A simple j-fet oscillator circuit is shown to the left.

You may have to tweak the values of C1 and C2 depending on the frequency range of the crystals your using, but the values shown should be good for most of the HF range. The type of JFET used isn't critical, nearly any N channel JFET should work. A socket for the crystals can be part of a dip socket. Since there isn't much to the circuit, it can be built “dead bug”, Manhattan Style, or by cutting “island” pads directly onto a copper clad board.

Entering Matching Mode:

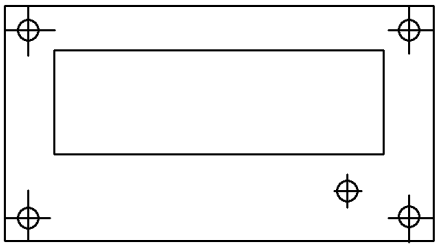
Before entering matching mode, you should check for proper oscillation and frequency of the crystal in the frequency counter mode. Once this is done, remove power from the counter, then click and hold the Mode switch closed and re-apply power to the counter. After the display test of all 8s, the display will read [cr .], at which time you can release the Mode switch. The counter will be in the crystal match mode, with a 1 second up date time. The display now shows the least significant frequency digits, with the last digit 10 Hz. The decimal point, however does not move from its normal position.

Crystal matching:

Insert the crystal you want to use as a reference frequency (if it is not already there) and click the Mode switch. This will zero out the display. Remove the “reference” crystal and insert a new crystal to be matched. Allow the oscillator and counter to stabilize for a few seconds. The display will now be indicating the difference (if any) from the reference crystal in 10 Hz increments. Disregard the decimal point, as it has no valid function in this mode. If the difference is negative, the display will indicate a [-] sign as the most significant digit, otherwise the MSD will be blank. Repetitively change crystals in the oscillator, sorting the crystals into groups dependent on their deviation from the “reference” until you have exhausted your supply of crystals. You can return to frequency counter mode by clicking the Mode switch at any time, but you have to re-zero with your reference crystal if you wish to continue matching.

Mounting the counter board

The drill drawing below can be printed out and used to locate the mounting holes, display cut out and switch location. Cutting the hole for the display can be a problem. The easiest method I've found is to use a Dremal cutting wheel. Using eye protection and a dust mask is recommended while doing this. Small as the counter board is, if your adding it to an existing rig, you may not have enough front panel space to mount it. One option is to mount it into the lid of the rig. The other is to make a little box for the counter and mount that to the lid of the rig. If at all possible, a red filter should be mounted in front of the display. This can be a piece of red transparency film, or some red plastic made specifically for LED display filters. This can be salvaged from an old LED clock radio or the like. Using a red filter will not only make your finished project look better, but will improve the readability of the display.



Parts List

Location	*value*	*type*	*qyanity*		*Ref color*
C1-6	0.1 uFd	0805 X7R 10%	(6 pieces)		BLUE
C7	22 pFd	0805 NPO 5%	(1 piece)		Orange
C8	47 uFd /16V	Alum electro	(1 piece)		
C9	30 pFd	Trimmer cap	(1 piece)		
R1	1 Meg	0805 5%	(1 piece)	105	
R2	2.2 K ohm	0805 5%	(1 piece)	222	
R3	100 K ohm	0805 5%	(1 piece)	104	
R4	1000 ohm	0805 5%	(1 piece)	102	
R5-12	2.2 K ohm	0805 5%	(8 pieces)	222	
L1	2.7 uHy	1206	(1 piece)	inductor	BLACK
U1	74HC4017	SO-16	(1 piece)	/10 counter	
U2	Tiny2313-10	SO-20	(1 piece)	MPU	Atmel
U3	L78L05UAC	SOT-89	(1 piece)	+5V reg	
Q1	MMBF310	SOT-23	(1 piece)	jfet	
Q2	MMBT5179	SOT-23	(1 piece)	NPN 900 MHz	
D1	SS-12	SMT	(1 piece)	1A shottky	
S1	TACT SW	6mm			
X1	10.0000 MHz	HU-49U	(1 piece)	Crystal	
DISPLAY	4 digit LED	LTC-4627	(1 piece)		
pcb	Circuit board				
4.7p	Ceramic disk	To connect to	Signal	Input at signal	source

How it works:

A signal applied to the counter input is first buffered by a high input impedance J-FET. The signal then goes to a high gain NPN stage, where it is “squared up” so that the frequency can be counted. The inductor in the collector improves gain at higher frequencies, while the resistor is the primary collector load at low frequencies.

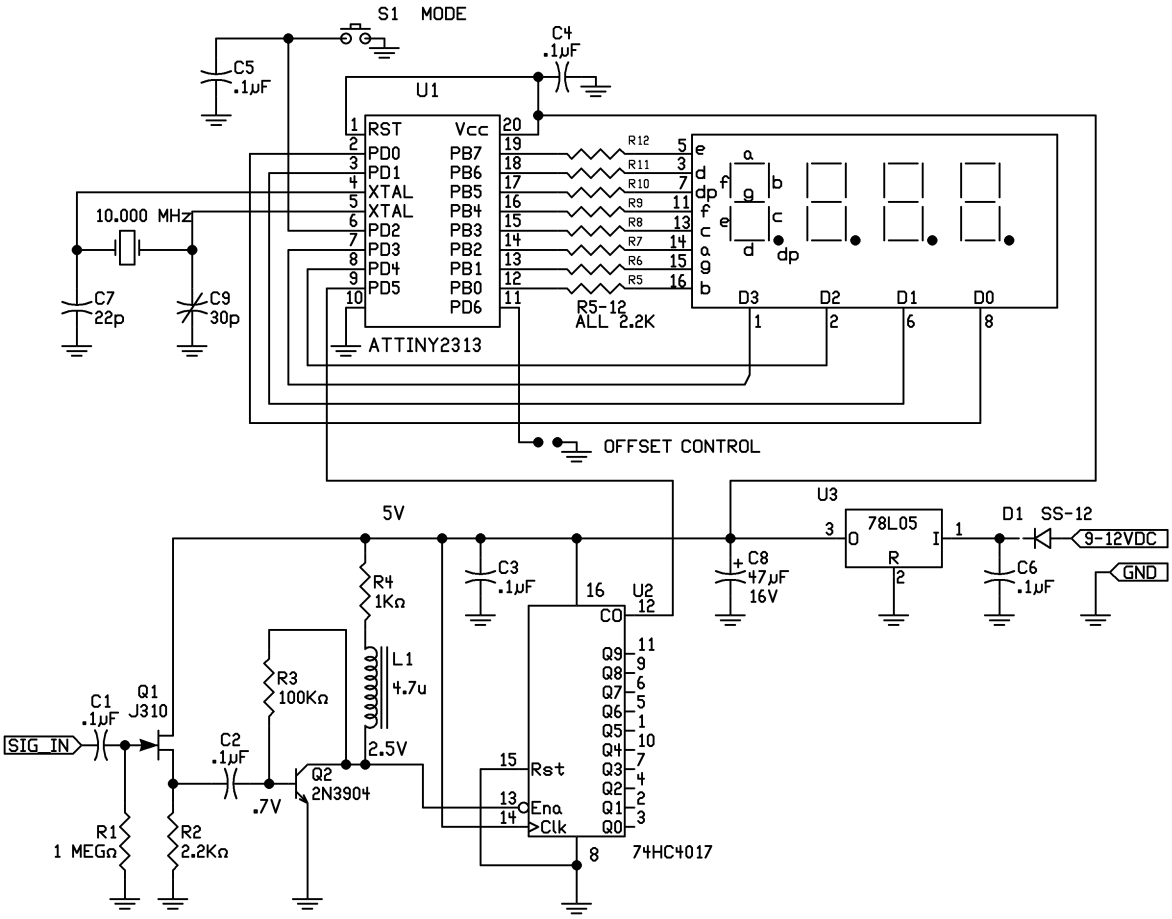
A 74HC4017 is used as a divide by 10 prescaler. The reason for this part is because of the fact the counter input of the MPU is sampled by the MPU system clock. This limits the maximum frequency which can be reliably detected by the MPU external counter input to be ½ the MPU clock frequency. If the signal were applied directly to the MPU external counter input, the highest frequency we could count would be about 5 MHz, assuming the maximum MPU clock of 10 MHz. By using the /10 prescaler, we can count 10 times higher, or nearly 50 MHz. Because the MPU input sampling isn't in lock with the input signal, in practice the input frequency can't be quite ½ the MPU clock, but must stay a little below that to get accurate sampling.

From here on out, the Atmel ATTINY2313 MPU (Micro Processor Unit) does everything. An internal timer allows the external count to be accumulated for 200 ms. A 200 ms conversion time, resulting in 50 Hz count resolution, was chosen so that the frequency display responds quickly to changing frequency input. A 1 second conversion time, while giving 10 Hz resolution, (due to the /10 prescaler) would be too sluggish to be used as a digital dial. In the crystal matching mode, the time base is changed to one second in order to give 10 Hz resolution, as in this case, a slow response time is not a problem.

Once the external frequency count has been accumulated, the resulting binary number is divide by 2 to obtain the final display resolution of 100 Hz. This helps reduce flickering of the 100 Hz digit. Any offsets required are added or subtracted from the count and then the binary number is converted to decimal. The decimal number is then converted to a 7 segment bit code required to display the number on the LED display.

The LED display is multiplexed, that is a number is shown on one of the four digit displays one at a time. This is done at a fast enough rate that it looks like all the digits are on to the eye. The multiplexing or scan rate is about 150 Hz, which is fast enough so that the eye doesn't see flicker, but slow enough noise from the multiplexing is unlikely to get into a rigs audio via the power supply connections. A low current, high efficiency display is used, so that it can be driven directly from the MPU, without the aid of transistor digit drivers.

Schematic


S1 MODE
C4 .1µF
C5 .1µF
U1
RST
PD0
PD1
XTAL
XTAL
PD2
PD3
PD4
PD5
Vcc
PB7
PB6
PB5
PB4
PB3
PB2
PB1
PB0
PD6
ATTINY2313
10.000 MHz
C7 22p
C9 30p
R12
R11
R10
R9
R8
R7
R6
R5
R5-12 ALL 2.2K
a
b
c
d
e
f
g
dp
D3
D2
D1
D0
OFFSET CONTROL
5V
U3
78L05
D1 SS-12
9-12VDC
GND
C8 47µF 16V
C6 .1µF
C3 .1µF
R4 1KΩ
L1 4.7u
R3 100KΩ
C1 .1µF
Q1 J310
SIG IN
C2 .1µF
Q2 2N3904
.7V
2.5V
R1 1 MEGΩ
R2 2.2KΩ
U2
CO
Q9
Q8
Q7
Q6
Q5
Q4
Q3
Q2
Q1
Q0
Rst
Ena
Clk
74HC4017

Working with SMT parts:

If you have never worked with surface mounted parts before, it's not very difficult and can be an enjoyable experience. This section describes the tools and techniques you will need.

Tools:

At a minimum, you will need:

1. Tweezers
2. Magnifier (visor, lighted, hand held glass, etc.)
3. Hobby knife, such as Xacto™ with #11 blade
4. Small tipped soldering iron, (1/16" conical or chisel) 25-30 watts or temperature controlled.
5. Needle noise pliers, diagonal cutters, small screw driver.
6. Good light
7. Steady hands.
8. Optional SMT part hold down device.

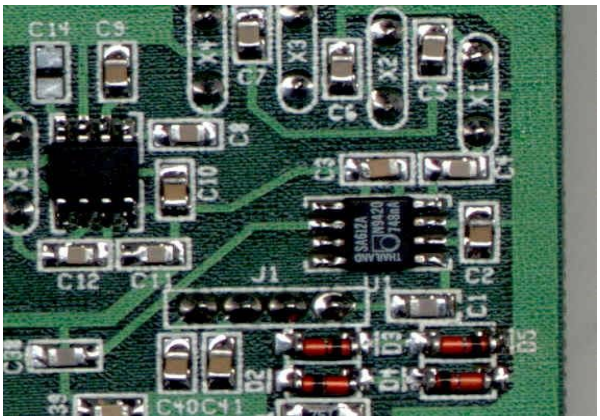
Instead of, or in addition to the tweezers, you can use a tooth pick with a dab of bee's wax on the end to make it sticky. With this, you can pick up the small parts and hold them down while you solder. A problem with tweezers can be if you grasp the part too tightly, it can spring out and go flying, never be seen again.

Removing the parts from the carrier

Many of the parts need to be removed from their carriers before use. A clear strip of plastic needs to be peeled off to expose the part for removal. To avoid loosing a part, this is best done by holding the carrier in one hand, in front of you and against your work surface, then peel off the plastic cover using your tweezers. Once the plastic is peeled off, tip the carrier over to drop out the parts in front of you.

Soldering:

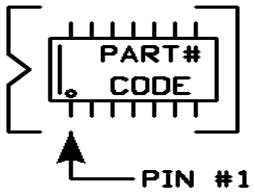
Some very thin (.020") solder is supplied with the kit for use with the SMT parts. (If you need more, Radio Shack sells this. Very little solder per connection is needed. Ideally, you want just a tiny concave fillet between the end of the part and the pad. The picture to the left shows examples of SMT soldering.



Chip caps, resistors and other two leaded parts.

1. Lightly tin one of the two pads.
2. Use the tip of your hobby knife or tweezers to peel back the clear cover on the parts carrier and then spill them out onto a clear work space above the board.
3. Pick up the part and place it over the pads. Try to keep it centered and squared over the pads.
4. Apply a little heat with the iron to tack the part to the tined pad.
5. Solder the other end, be sure to heat both the end of the part and the pad at the same time.
6. If needed, return to the tacked end and apply a little fresh solder. Resistors are more likely to need this than capacitors.
7. When placing a number of the same value part to the board, you can speed things up a bit by tinning the pads for several locations at once. Tack the parts down and go back and do the other end. Just be sure not to miss any!

Finding Pin 1



Some SMT ICs, but not all have pin 1 marked by a dot or dimple, such as their larger through hole versions. In some cases, you have to go by the way in which the printing on the is orientated. When the printing is orientated so that it reads "proper", i.e., left to right, top to bottom, **Pin 1 is ALWAYS in the LOWER LEFT CORNER.** Often, the manufacturers logo will appear at the pin 1 location, or there maybe a line on the pin 1 end. Pin 1 is mounted on the board facing the notched end of the outline.

Soldering IC's

1. Lightly tin one corner pad.
2. Place the IC and line up the pins over the pads A little dab of Bee's wax under the chip can help hold it in place.
3. Tack down the corner pin to the tinned pad.
4. Verify the lead alignment on the pads. This is very important!
5. Proceed to solder the rest of the pins to the pads, usually starting at the opposite corner from the one you just tacked down. Ideally, you want a little solder to flow between the IC pin and pad. Therefore, don't hold the IC against the board very tightly, just enough pressure to keep it from moving as you tack the first pin.
6. Don't worry much about making solder shorts, especially with the fine lead spaced parts. See step #7.
7. Inspect the soldering with your magnifying glass. If there are any solder shorts, use solder wick to remove the bridge. Use the tip of the hobby knife to gently 'Nudge" the leads. If any of them move, you didn't get them to stick to the pad and need to be touched up.

Removing IC's

Should you ever need to remove a SMT IC, with out damage to the part or the board tracks, this is the way to do it. First, wick as much solder as possible from the leads. Now feed a piece of #32 magnet wire between the leads and the body of the IC. Secure one end of the wire to something on the board. Now grab the free end of the wire and as you heat the first pin on the IC, pull the wire out between the lead and the track. Keep doing this for each pin in line down the chip. Repeat for the other side. The IC will now pretty much just pop off the board. (But you might have to loosen up one or two of the end pins with a tad more heat)

Using Liquid Solder Flux:

Some people like to use liquid solder flux. Since it usually makes a mess, I don't. If you do use it, be sure to clean the board very well afterwards!

Frequency counter / Digital Dial

The Digital Dial is primarily intended to be used as a simple means of adding a digital frequency read out to single band QRP radios. A programmable IF offset feature allows the counter to measure the VFO frequency but display the actual operating frequency. The digital dial can also be used as a general purpose frequency counter. It also includes a special “crystal matching” mode, which allows the matching of crystals used in IF filters to with in 10 Hz of each other.

Specifications:

Frequency range: 100 kHz to 45 MHz
Resolution: 100 Hz displayed, 50 Hz internal
Update rate: 200 ms
Input level: 50 mv to 100 mv p-p min, 2 V p-p max. (sensitivity varies with freq)
Input impedance: 1 Meg ohm.
Display, four digit LED
Supply voltage: 8 V min, 14 V max
Supply current: 37 ma, typical
Size: 2.1” wide, 1.1” high, 0.5” deep

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Manual updated 6/8/11

Assembly:

Empty the contents of the static bag into a soup or cereal bowel. This will help keep you from losing any of the small parts.

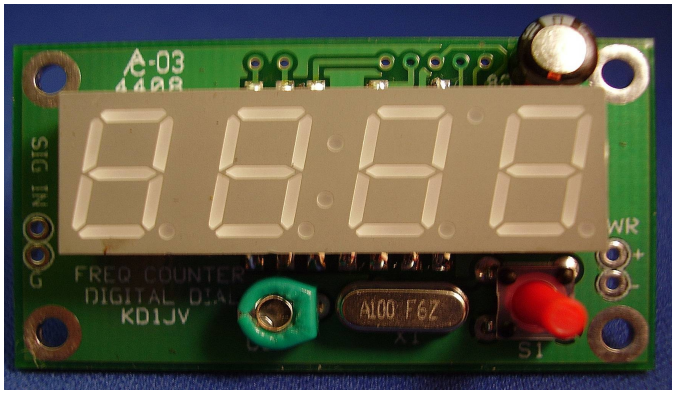
In order to make identifying the SMT parts easier, some of the parts have been color coded. The colors indicated on the layout diagram corresponds to the color marked on the SMT carrier package.

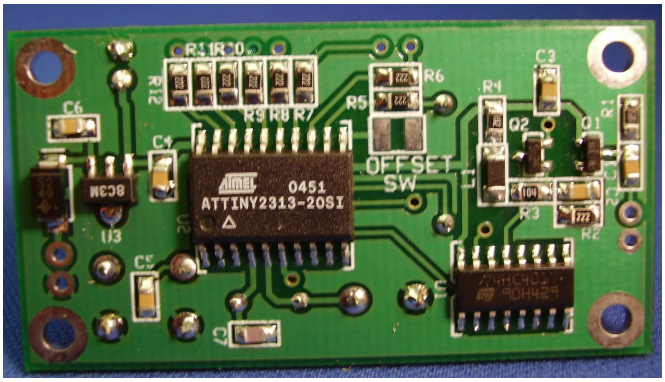
So that you do not mix up the parts, work with only one type of parts at a time. If there is more than one value used, place all of them before moving onto another.

Surface mounted parts are installed first. All of these go on the back side of the board. If this is the first time you've assembled anything using SMT parts, please refer to the “Building with SMT parts” appendix at the end of the manual.

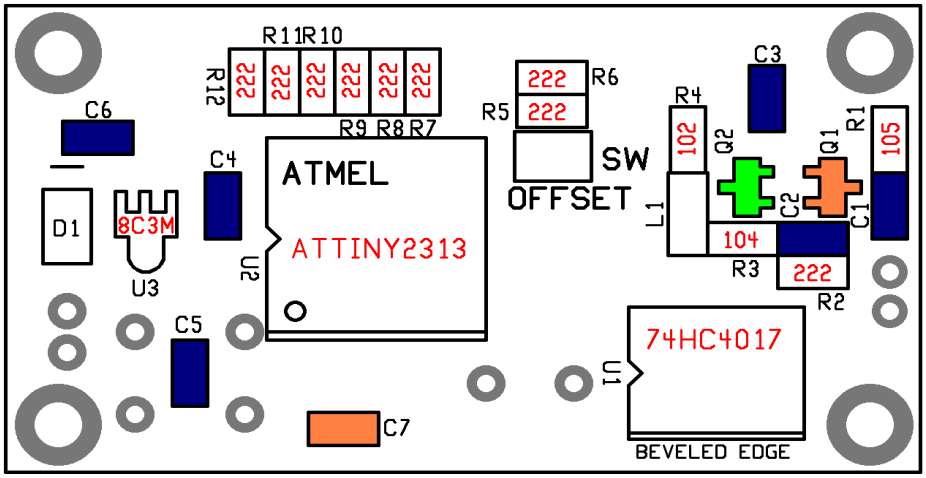
Solder: Do not use your usual solder, which is often 0.032” in diameter. Get some 0.020” solder, silver bearing is best. Radio Shack sell small rolls of this kind of solder.

Use these pictures to help locate and identify parts. Zoom in with the magnifier in the pdf viewer for a closer look.





Assembly: Back side

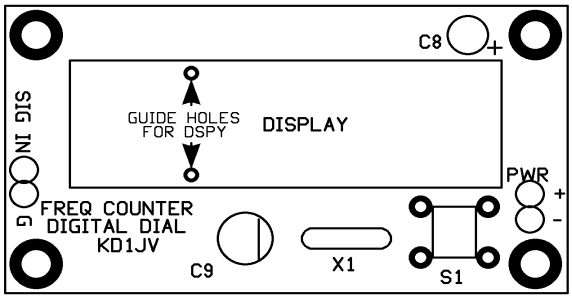


Recommended parts placement order shown in table:

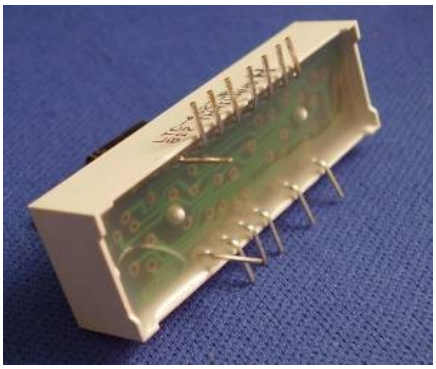
Note: Avoid pushing leads on Q1 and Q2 sideways when soldering, or it can damage the internal connections. Note beveled edge on U1 for proper orientation . Part number will also be in same orientation as shown in diagram. Note white line on D1 package, which will face towards the line above the D1 outline in diagram above.

√	*color*	*location*	*markings*	*type*	*quantity*
	ORANGE	Q1	6T N	.j-fet	1
	GREEN	Q2	3C f	NPN	1
	BLUE	C1 to 6	None, tan	0.1 uFd cap	6
	ORANGE	C7	None, tan	22 pFd cap	1
		R2 - R5 to 12	222	2.2K Ω	9
		R1	105	1 Meg	1
		R3	104	100K	1
		R4	102	1K	1
		L1	None, black	4.7 uHy	1
	----------	D1	S2 49	Diode	1
	----------	U1	74HC4017	counter	1
	----------	U2	Tiny2313	MPU	1
	----------	U3	8C3M	5V reg	1

Front side parts:



Display:



The display is soldered into place first. This requires a little rework before it can be done. All *but the two left most pins* need to be bent out at a 90º angle to the body as can be seen in the photo to the left. The part numbering on the side of the display indicates the bottom side, the side which will mount towards S1, X1 and C9. Simply fold the leads over with your thumb or needle noise pliers.

Once the leads are bent over, clip them back about half their length, so that the pins do not go beyond the edge of the pads on the board. Now the display can be soldered to the pads on the board. The two display leads which have not been bent to a right angle go into the two holes in the board as shown in the placement diagram above. This helps to ensures the display will be not end up crooked on the board. However, before soldering the pins in place, make sure it is parallel to the board and the corners of the display are flat to the board.

Once the display is soldered into place, proceed with the four remaining through hole parts.

C9	Green trimmer		
C8	47 uF/ 16V	Long lead +	
X1	10.00 MHz	crystal	
S1	TACT switch		

Note: the flat side of C9 mounts towards the line in the outline on the board.

Assembly of the counter is now complete. Now is a good time to inspect your workmanship and look for any solder connections you might have missed making. Look closely at both ends of the chip resistors and capacitors.

Test and calibration:

Connect up a power supply, a 9 V battery will do for now.
When power is applied, the display should light up with four eights and four decimal points for a couple of seconds. [8.8.8.8] This is the display test.

Once the display test is over, the counter will be in the kHz frequency counter mode. Due to stray pick up by the high impedance input, you will see random numbers flickering on the display. Short the [SIG IN] terminals and the display should now read all zeros. [000.0] Confirm Mode switch operation by clicking and verify display changes to MHz range [00.00] Clicking and holding close the Mode switch for one second should turn off the display. Clicking again turns the display back on.

Trouble shooting:

There isn't a whole lot which can go wrong with this board. If it does not work first time, there is a 99.999% chance the problem is with the soldering of parts. Therefore, this is what you need to look for first. The other .001% is a misplaced part.

Calibration:

The counter needs to be calibrated before it will measure accurately. This is done by adjusting the green trimmer on the front of the board. The trimmer has a range of about +/- 700 Hz at 10 MHz. The exact range is dependent on the frequency inputed to the counter. Higher frequencies will have a larger apparent range than lower ones. If no accurate frequency source is available for calibration, centering the trimmer cap in its adjustment range (45 degree turn from factory setting) will put it reasonably close.

An accurate signal source is required and should be done at the highest frequency available, which is in the range of the counter (45 MHz). For most of you, the most accurate signal source you may have available is your commercial “Big Rig”, and the highest frequency available will be in the 10 M band. In CW mode, most rigs transmit on the frequency indicated by the dial. You should of course, transmit into a dummy load. If the dummy load is well shielded, you might have to put a coax “T” connector in series with the cable going to the dummy load and add a short “antenna” wire to the tap. With a similar short antenna on the counter input, you will likely get enough signal to get a stable display on the counter. A more reliable method might be to use a resistor divider across the dummy load, say a 100 K in series with a 1 K resistor. The counter input would be connected across the 1 K resistor and the 100 K to the top of the dummy load. Start with as little power output from the rig as possible, then if needed, increase to get a stable reading on the counter.

Operation:

The digital dial is controlled by a single switch, which we will call the “Mode” switch. This switch may have more than one function, depending on the mode in which the digital dial is being used.

As a frequency counter:

The first time power is applied to the digital dial, it will power up in the frequency counter mode. Since the counter can count up to 45 MHz and there are only four digits of display, there is a “display shift” function.

On power up, the kHz and 100 Hz digits are displayed. This is indicated by the decimal point being to the right of the third digit. The most significant digit is indicating 100 kHz and the least significant digit is indicating 100 Hz, or .1 kHz.

To display the MHz digits, click the Mode switch.

The decimal point will now shit the the left one digit, so that it is to the right of the second digit. The display is now indicating 10's of MHz in the most significant digit and 10 kHz in the least significant digit.

Sleep Mode:

In order to reduce current consumption when the counter isn't being used, there is a Sleep Mode function. This turns off the display and powers down the MPU. The input circuits and counter are still under power, so current is reduced to only about 15 ma.

Activating Sleep Mode:

Click and hold the Mode switch for about one (1) second, until the display goes blank.

Waking up the display:

Click the Mode switch again to wake up the MPU and turn the display back on.

Using as a Digital Dial:

In most radios, an IF offset will need to be programmed into the counter in order to indicate the operating frequency of the rig. This is because the IF frequency is often a fractional MHz frequency, such as 4.91520 MHz. If the IF frequency has no fractional component, such as 9.000000 MHz, there is no real need to program an offset, provided one is only interested in reading the kHz part of the operating frequency.

There are three possible combinations of VFO and IF frequencies to obtain the operating frequency. These are:

1. VFO + IF = op freq
2. VFO - IF = op freq
3. IF - VFO = op freq

In the case of #1 and #2, the operating frequency increases as the VFO frequency increases. In the case of #3, the operating frequency increases as the VFO frequency decreases. All three of these cases can be handled by the counter, but you will need to know which combination of VFO and IF mixing your rig uses to program the correct mixing scheme into the counter.

The simplest way to get the IF frequency into the counter is to use the counter to measure the BFO frequency, so this is what we do. However, in a CW rig, the BFO frequency is typically set about 600 Hz higher than the operating or transmit frequency in order to hear the proper CW beat note. In some cases, the BFO will be on the low side of the transmit frequency, but this is rare. In SSB rigs, the BFO will be at the transmit frequency, as there is no offset for SSB reception.

If left uncorrected the BFO CW offset will result in the dial reading 600 Hz higher (or lower) than the transmit frequency. If the receiver has a BFO trimmer (and many do), you can use that to lower the BFO frequency by 600 Hz before programming the offset. This is easy enough to do, since you have the counter connected to the BFO anyway. After programming the offset, re-tune the BFO trimmer.

Programming the IF offset:

The first thing to do is connect the counter to your BFO oscillator. In some rigs, this will be a separate oscillator from the BFO mixer. (Such as 2N2xx rig builders) In many QRP rigs, the BFO oscillator is part of a SA612. In the case of a separate oscillator, connect the signal input to the counter to where the BFO feeds the BFO mixer. In the case of a rig using the SA612, connect the counter to pin 7 of the SA612 (or NE602, SA602) using the supplied 4.7 pfd cap in series with the cable going to the counter. This small capacitor will reduce loading on the oscillator so not to shift the frequency significantly or possibly causing the oscillator to stop working.

The counter should now be indicating the BFO frequency on the display. If it is reading all zeros, then your not getting enough signal and may have to use a larger coupling cap to the counter.

Entering the IF offset program mode:

The offset program mode is entered by momentarily shorting the two pads on the back of the counter board marked “OFFSET SW” This needs to be done only once, so you can just use a short piece of wire to tap a short across the pads.

Once the two pads marked “OFFSET SW” are shorted together, the display will change to indicate [LO - -]

The proper IF offset mode is then selected using the Mode switch on the front of the counter. Each time the switch is clicked, it will advance to the next mode. The display indicates these selections as such:

[LO - A] VFO + IF = op freq
[LO - b] VFO - IF = op freq
[LO - c] IF - VFO = op freq
[LO - o] clear offset from memory.

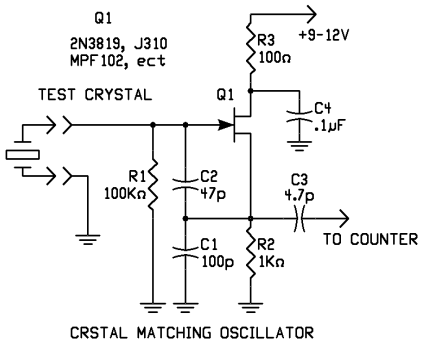
Once the proper selection has been made, click and hold closed the mode switch for one (1) second. If the clear offset was selected, the counter will go back to being a frequency counter. If selection “A” was made, IF+VFO, the frequency reading will be double what it was. If one of the other two modes were selected, the frequency reading will now be zero. If you adjusted the BFO trimmer, reset it now. You can now disconnect the counter from the BFO and connect it to your VFO.

Connecting the counter to the VFO:

The counter should be connected to the same point as which drives the receiver mixer. If the VFO is not buffered, try using the supplied 4.7p cap in series with the cable going to the counter, at the signal source. If there is enough signal level there to allow using this cap, it will reduce any possible loading effects of the connecting cable. Depending on the VFO frequency and output level, you might have to use a larger value coupling cap to get a stable reading on the counter. For short runs from the VFO to the counter, a twisted pair can be used. For longer runs, say more than 3-4 inches, shield cable, such as RG-174 coax should be used.

Display multiplexing noise on supply line.

Noise from the display multiplexing on the power supply line and then into the audio of a rig maybe possible. LED segment current has been reduce in this latest version of the DDial, as compared to earlier versions, which has significantly reduced the problem. If however, you do hear noise from the display, adding a series resistor (100 ohms to 220 ohms, depending on the supply voltage) and a filter cap at the board side of the series resistor (100 uFd or larger) will eliminate the problem. However, this will increase the minimum supply voltage requirement some.



CRSTAL MATCHING OSCILLATOR

Crystal Matching mode:

This mode allows you to match crystals to within 10 Hz of each other. By matching crystals closely, you can build very narrow CW ladder filters. You will of course, need a crystal oscillator to do this. A simple j-fet oscillator circuit is shown to the left.

You may have to tweak the values of C1 and C2 depending on the frequency range of the crystals your using, but the values shown should be good for most of the HF range. The type of JFET used isn't critical, nearly any N channel JFET should work. A socket for the crystals can be part of a dip socket. Since there isn't much to the circuit, it can be built “dead bug”, Manhattan Style, or by cutting “island” pads directly onto a copper clad board.

Entering Matching Mode:

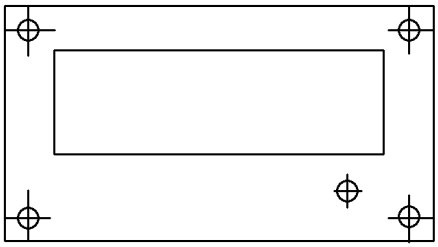
Before entering matching mode, you should check for proper oscillation and frequency of the crystal in the frequency counter mode. Once this is done, remove power from the counter, then click and hold the Mode switch closed and re-apply power to the counter. After the display test of all 8s, the display will read [cr .], at which time you can release the Mode switch. The counter will be in the crystal match mode, with a 1 second up date time. The display now shows the least significant frequency digits, with the last digit 10 Hz. The decimal point, however does not move from its normal position.

Crystal matching:

Insert the crystal you want to use as a reference frequency (if it is not already there) and click the Mode switch. This will zero out the display. Remove the “reference” crystal and insert a new crystal to be matched. Allow the oscillator and counter to stabilize for a few seconds. The display will now be indicating the difference (if any) from the reference crystal in 10 Hz increments. Disregard the decimal point, as it has no valid function in this mode. If the difference is negative, the display will indicate a [-] sign as the most significant digit, otherwise the MSD will be blank. Repetitively change crystals in the oscillator, sorting the crystals into groups dependent on their deviation from the “reference” until you have exhausted your supply of crystals. You can return to frequency counter mode by clicking the Mode switch at any time, but you have to re-zero with your reference crystal if you wish to continue matching.

Mounting the counter board

The drill drawing below can be printed out and used to locate the mounting holes, display cut out and switch location. Cutting the hole for the display can be a problem. The easiest method I've found is to use a Dremal cutting wheel. Using eye protection and a dust mask is recommended while doing this. Small as the counter board is, if your adding it to an existing rig, you may not have enough front panel space to mount it. One option is to mount it into the lid of the rig. The other is to make a little box for the counter and mount that to the lid of the rig. If at all possible, a red filter should be mounted in front of the display. This can be a piece of red transparency film, or some red plastic made specifically for LED display filters. This can be salvaged from an old LED clock radio or the like. Using a red filter will not only make your finished project look better, but will improve the readability of the display.



Parts List

Location	*value*	*type*	*qyanity*		*Ref color*
C1-6	0.1 uFd	0805 X7R 10%	(6 pieces)		BLUE
C7	22 pFd	0805 NPO 5%	(1 piece)		Orange
C8	47 uFd /16V	Alum electro	(1 piece)		
C9	30 pFd	Trimmer cap	(1 piece)		
R1	1 Meg	0805 5%	(1 piece)	105	
R2	2.2 K ohm	0805 5%	(1 piece)	222	
R3	100 K ohm	0805 5%	(1 piece)	104	
R4	1000 ohm	0805 5%	(1 piece)	102	
R5-12	2.2 K ohm	0805 5%	(8 pieces)	222	
L1	2.7 uHy	1206	(1 piece)	inductor	BLACK
U1	74HC4017	SO-16	(1 piece)	/10 counter	
U2	Tiny2313-10	SO-20	(1 piece)	MPU	Atmel
U3	L78L05UAC	SOT-89	(1 piece)	+5V reg	
Q1	MMBF310	SOT-23	(1 piece)	jfet	
Q2	MMBT5179	SOT-23	(1 piece)	NPN 900 MHz	
D1	SS-12	SMT	(1 piece)	1A shottky	
S1	TACT SW	6mm			
X1	10.0000 MHz	HU-49U	(1 piece)	Crystal	
DISPLAY	4 digit LED	LTC-4627	(1 piece)		
pcb	Circuit board				
4.7p	Ceramic disk	To connect to	Signal	Input at signal	source

How it works:

A signal applied to the counter input is first buffered by a high input impedance J-FET. The signal then goes to a high gain NPN stage, where it is “squared up” so that the frequency can be counted. The inductor in the collector improves gain at higher frequencies, while the resistor is the primary collector load at low frequencies.

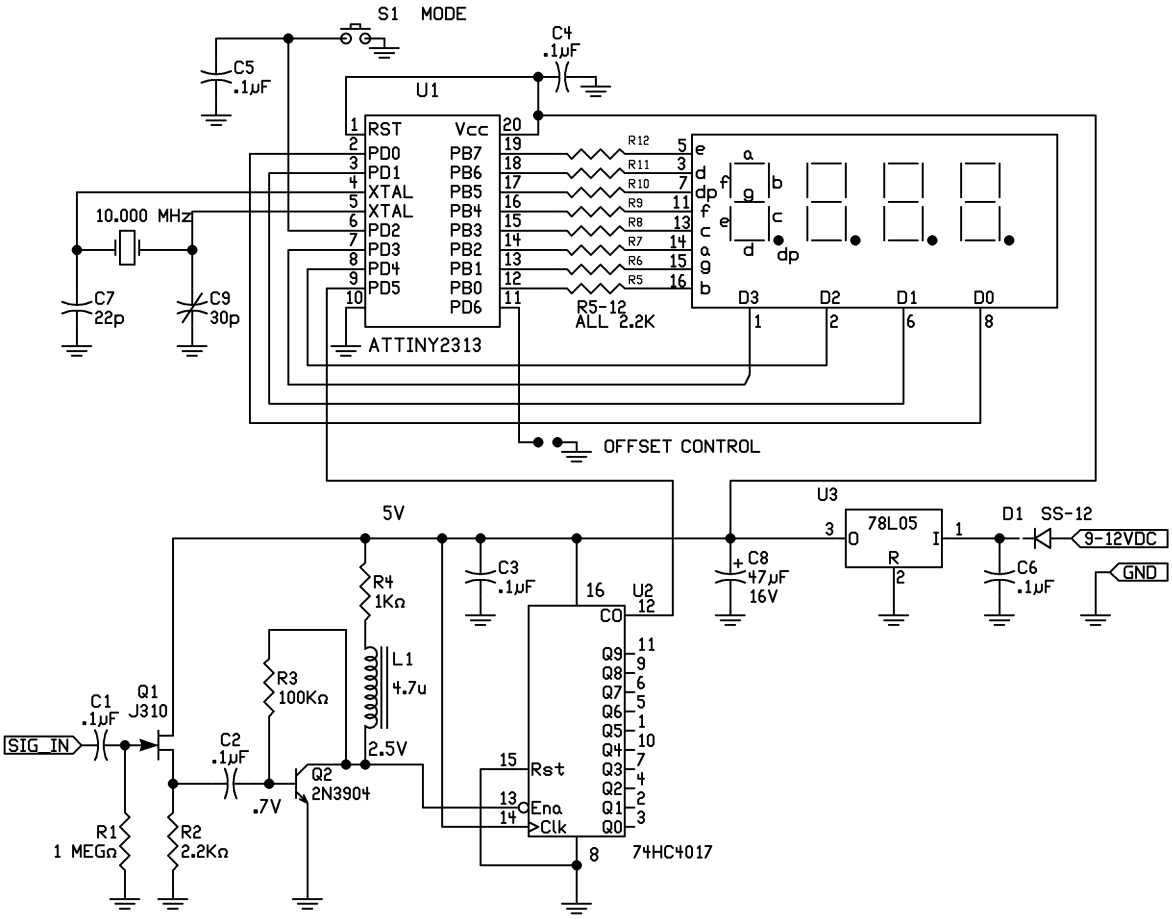
A 74HC4017 is used as a divide by 10 prescaler. The reason for this part is because of the fact the counter input of the MPU is sampled by the MPU system clock. This limits the maximum frequency which can be reliably detected by the MPU external counter input to be ½ the MPU clock frequency. If the signal were applied directly to the MPU external counter input, the highest frequency we could count would be about 5 MHz, assuming the maximum MPU clock of 10 MHz. By using the /10 prescaler, we can count 10 times higher, or nearly 50 MHz. Because the MPU input sampling isn't in lock with the input signal, in practice the input frequency can't be quite ½ the MPU clock, but must stay a little below that to get accurate sampling.

From here on out, the Atmel ATTINY2313 MPU (Micro Processor Unit) does everything. An internal timer allows the external count to be accumulated for 200 ms. A 200 ms conversion time, resulting in 50 Hz count resolution, was chosen so that the frequency display responds quickly to changing frequency input. A 1 second conversion time, while giving 10 Hz resolution, (due to the /10 prescaler) would be too sluggish to be used as a digital dial. In the crystal matching mode, the time base is changed to one second in order to give 10 Hz resolution, as in this case, a slow response time is not a problem.

Once the external frequency count has been accumulated, the resulting binary number is divide by 2 to obtain the final display resolution of 100 Hz. This helps reduce flickering of the 100 Hz digit. Any offsets required are added or subtracted from the count and then the binary number is converted to decimal. The decimal number is then converted to a 7 segment bit code required to display the number on the LED display.

The LED display is multiplexed, that is a number is shown on one of the four digit displays one at a time. This is done at a fast enough rate that it looks like all the digits are on to the eye. The multiplexing or scan rate is about 150 Hz, which is fast enough so that the eye doesn't see flicker, but slow enough noise from the multiplexing is unlikely to get into a rigs audio via the power supply connections. A low current, high efficiency display is used, so that it can be driven directly from the MPU, without the aid of transistor digit drivers.

Schematic


S1 MODE
C4 .1µF
C5 .1µF
U1
RST
PD0
PD1
XTAL
XTAL
PD2
PD3
PD4
PD5
Vcc
PB7
PB6
PB5
PB4
PB3
PB2
PB1
PB0
PD6
ATTINY2313
10.000 MHz
C7 22p
C9 30p
R12
R11
R10
R9
R8
R7
R6
R5
R5-12 ALL 2.2K
a
b
c
d
e
f
g
dp
D3
D2
D1
D0
OFFSET CONTROL
5V
U3
78L05
D1 SS-12
9-12VDC
GND
C8 47µF 16V
C6 .1µF
C3 .1µF
R4 1KΩ
L1 4.7u
R3 100KΩ
C1 .1µF
Q1 J310
SIG IN
C2 .1µF
Q2 2N3904
.7V
2.5V
R1 1 MEGΩ
R2 2.2KΩ
U2
CO
Q9
Q8
Q7
Q6
Q5
Q4
Q3
Q2
Q1
Q0
Rst
Ena
Clk
74HC4017

Working with SMT parts:

If you have never worked with surface mounted parts before, it's not very difficult and can be an enjoyable experience. This section describes the tools and techniques you will need.

Tools:

At a minimum, you will need:

1. Tweezers
2. Magnifier (visor, lighted, hand held glass, etc.)
3. Hobby knife, such as Xacto™ with #11 blade
4. Small tipped soldering iron, (1/16" conical or chisel) 25-30 watts or temperature controlled.
5. Needle noise pliers, diagonal cutters, small screw driver.
6. Good light
7. Steady hands.
8. Optional SMT part hold down device.

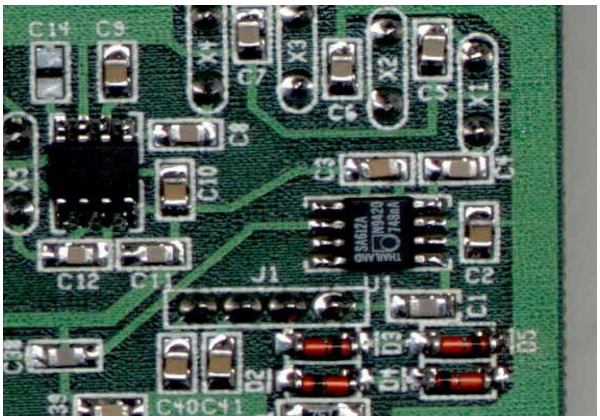
Instead of, or in addition to the tweezers, you can use a tooth pick with a dab of bee's wax on the end to make it sticky. With this, you can pick up the small parts and hold them down while you solder. A problem with tweezers can be if you grasp the part too tightly, it can spring out and go flying, never be seen again.

Removing the parts from the carrier

Many of the parts need to be removed from their carriers before use. A clear strip of plastic needs to be peeled off to expose the part for removal. To avoid loosing a part, this is best done by holding the carrier in one hand, in front of you and against your work surface, then peel off the plastic cover using your tweezers. Once the plastic is peeled off, tip the carrier over to drop out the parts in front of you.

Soldering:

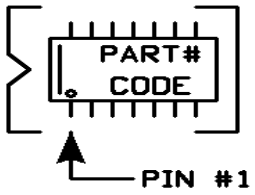
Some very thin (.020") solder is supplied with the kit for use with the SMT parts. (If you need more, Radio Shack sells this. Very little solder per connection is needed. Ideally, you want just a tiny concave fillet between the end of the part and the pad. The picture to the left shows examples of SMT soldering.



Chip caps, resistors and other two leaded parts.

1. Lightly tin one of the two pads.
2. Use the tip of your hobby knife or tweezers to peel back the clear cover on the parts carrier and then spill them out onto a clear work space above the board.
3. Pick up the part and place it over the pads. Try to keep it centered and squared over the pads.
4. Apply a little heat with the iron to tack the part to the tined pad.
5. Solder the other end, be sure to heat both the end of the part and the pad at the same time.
6. If needed, return to the tacked end and apply a little fresh solder. Resistors are more likely to need this than capacitors.
7. When placing a number of the same value part to the board, you can speed things up a bit by tinning the pads for several locations at once. Tack the parts down and go back and do the other end. Just be sure not to miss any!

Finding Pin 1



Some SMT ICs, but not all have pin 1 marked by a dot or dimple, such as their larger through hole versions. In some cases, you have to go by the way in which the printing on the is orientated. When the printing is orientated so that it reads "proper", i.e., left to right, top to bottom, **Pin 1 is ALWAYS in the LOWER LEFT CORNER.** Often, the manufacturers logo will appear at the pin 1 location, or there maybe a line on the pin 1 end. Pin 1 is mounted on the board facing the notched end of the outline.

Soldering IC's

1. Lightly tin one corner pad.
2. Place the IC and line up the pins over the pads A little dab of Bee's wax under the chip can help hold it in place.
3. Tack down the corner pin to the tinned pad.
4. Verify the lead alignment on the pads. This is very important!
5. Proceed to solder the rest of the pins to the pads, usually starting at the opposite corner from the one you just tacked down. Ideally, you want a little solder to flow between the IC pin and pad. Therefore, don't hold the IC against the board very tightly, just enough pressure to keep it from moving as you tack the first pin.
6. Don't worry much about making solder shorts, especially with the fine lead spaced parts. See step #7.
7. Inspect the soldering with your magnifying glass. If there are any solder shorts, use solder wick to remove the bridge. Use the tip of the hobby knife to gently 'Nudge" the leads. If any of them move, you didn't get them to stick to the pad and need to be touched up.

Removing IC's

Should you ever need to remove a SMT IC, with out damage to the part or the board tracks, this is the way to do it. First, wick as much solder as possible from the leads. Now feed a piece of #32 magnet wire between the leads and the body of the IC. Secure one end of the wire to something on the board. Now grab the free end of the wire and as you heat the first pin on the IC, pull the wire out between the lead and the track. Keep doing this for each pin in line down the chip. Repeat for the other side. The IC will now pretty much just pop off the board. (But you might have to loosen up one or two of the end pins with a tad more heat)

Using Liquid Solder Flux:

Some people like to use liquid solder flux. Since it usually makes a mess, I don't. If you do use it, be sure to clean the board very well afterwards!

MY FIRST (HOMEMADE) SHORTWAVE RECEIVER
10 kHz - 30 MHz

(1997)



This simple homemade RX gives me much more fun than a much better commercial receiver!

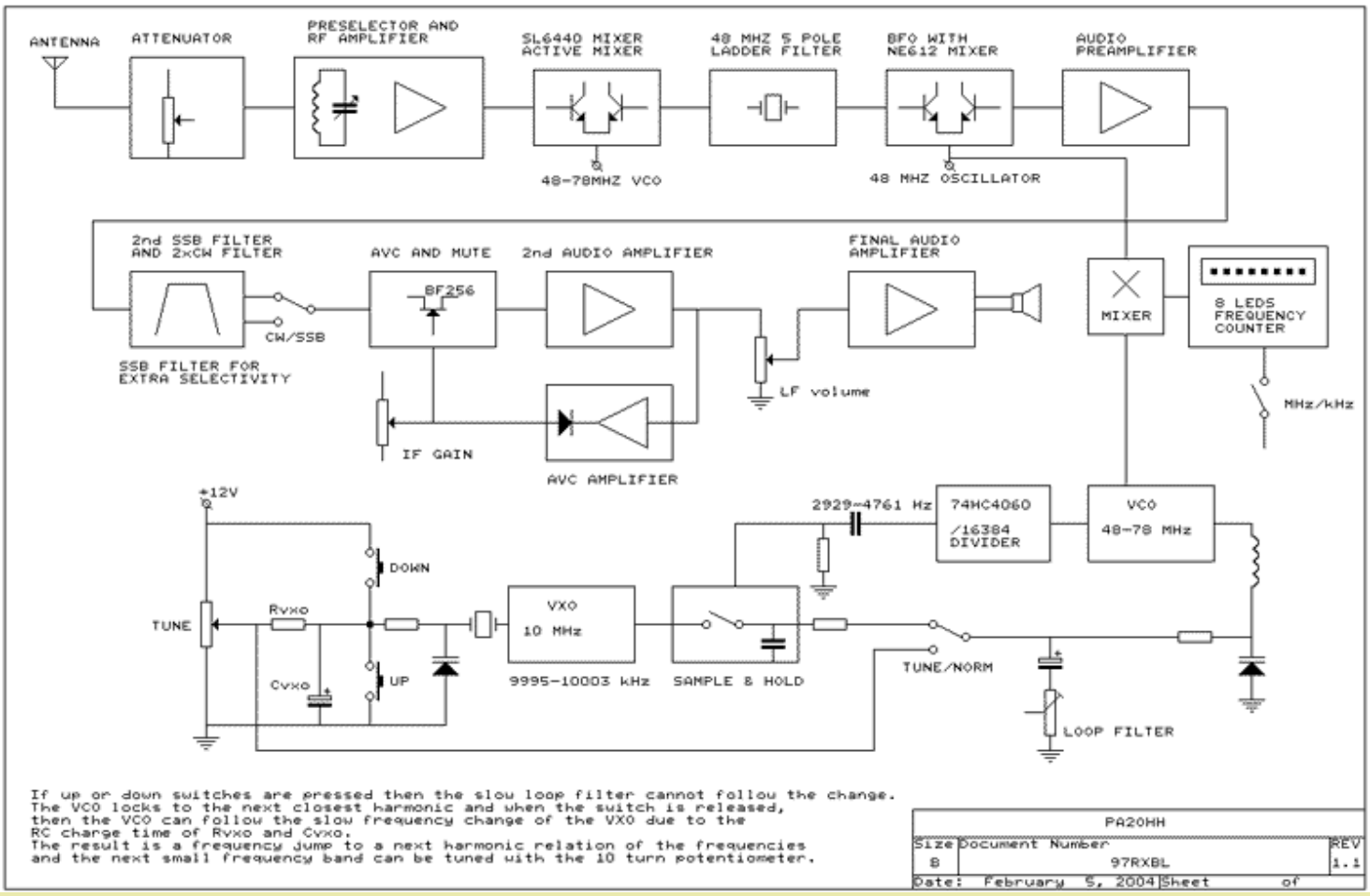
My first (homemade) SSB and CW receiver 10 kHz to 30 MHz
When I made a new start with my old radio hobby, the first item to solve was how to construct something in such a way that the prototype is also useable as the final version. The usual way is to make a prototype, then design the PCB's, make the final version and hopefully a lot of the parts of the prototype can be used again. Finally you will have a nice sample, but without any possibilities for modifications afterwards.
The second item to solve was how to find an easy way to make a nice housing for the equipment with text labels etc.

As I did not have a shortwave receiver anymore, that would be a nice project to try out how it is to work with "dead bug" construction on unetched PCB.
For the housing of the receiver I bought a standard 19 inch cabinet and found a way to make good looking text labels on it with a label printer and the window function.

Did I like the construction?
The "dead bug" construction method on unetched PCB was a very nice method to make a prototype, also useable as the final version. Use of a standard housing with text labels is a very easy and fast method to make a nice enclosure.

And the receiver?
It is a big but not so very complex and stable receiver, used almost daily to receive all kinds of signals such as 28 MHz beacons, amateurs, the clubstation, ships, new 5 MHz amateur bands in the UK, 518 kHz Navtex, DCF77 time signal decoding at 77.5 kHz. It is stable enough to receive all kinds of digital modes.

Recently modified
However, a second shortwave receiver was made, simpler, smaller and with a better VFO stabilizer circuit. Due to the unique construction method it was quite easy to make modifications and improve the VFO and AVC circuit of this receiver as a result of the experiences with the new shortwave receiver.

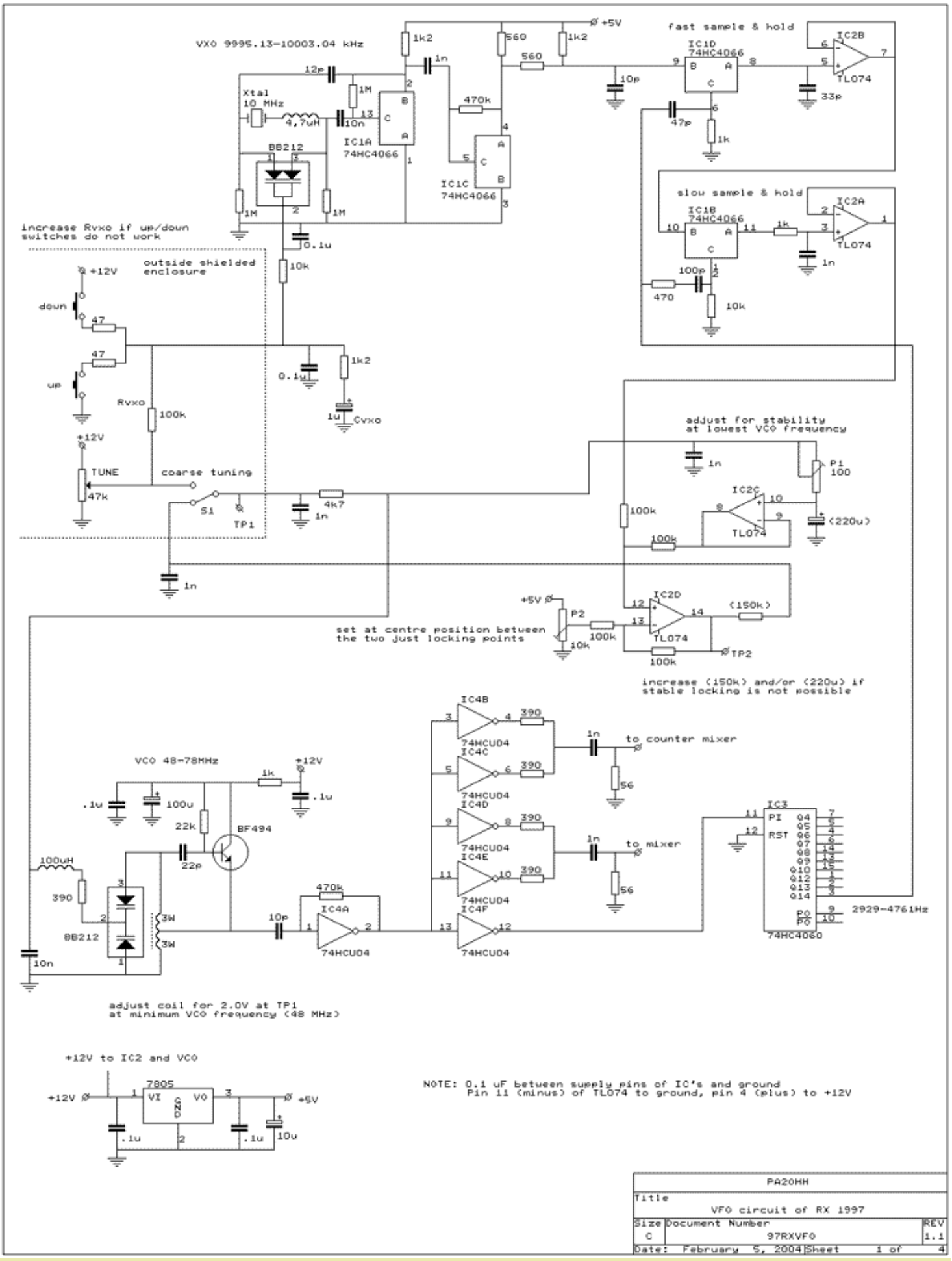


Block diagram.

Why is it so simple?
There are a few reasons for the simplicity.

- The VFO with simple stabilizer that runs from 48 MHz to 78 MHz but that combines a high stability with very comfortable tuning.
- Only one IF frequency with a crystal filter at 48 MHz, no IF amplifier.
- CW filtering and AVC is done in the LF circuits.
- The frequency counter is very simple.

The VFO


VXO 9995.13-10003.04 kHz
Xtal 10 MHz
4,7uH
12p
1M
10n
IC1A 74HC4066
BB212
IC1C 74HC4066
1k2
1n
560
470k
+5V
fast sample & hold
IC1D 74HC4066
IC2B
TL074
10p
33p
47p
1k
slow sample & hold
IC1B 74HC4066
IC2A
100p
470
increase Rvxo if up/doun switches do not work
outside shielded enclosure
+12V
doun
up
47
Rvxo
100k
0.1u
10k
1u
Cvxo
TUNE
47k
coarse tuning
S1
TP1
4k7
adjust for stability at louest VCO frequency
P1 100
IC2C
(220u)
set at centre position between the two just locking points
P2
IC2D
(150k)
TP2
increase (150k) and/or (220u) if stable locking is not possible
VCO 48-78MHz
.1u
100u
22k
BF494
22p
100uH
390
3W
IC4B
IC4C
IC4D
IC4E
IC4F
74HCU04
to counter mixer
to mixer
56
IC3
PI
RST
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Q12
Q13
Q14
P0
74HC4060
2929-4761Hz
adjust coil for 2.0V at TP1 at minimum VCO frequency (48 MHz)
+12V to IC2 and VCO
7805
VI
VO
GND
NOTE: 0.1 uF between supply pins of IC's and ground
Pin 11 (minus) of TL074 to ground, pin 4 (plus) to +12V
PA2OHH
Title
VFO circuit of RX 1997
Size C
Document Number 97RXVFO
REV 1.1
Date: February 5, 2004
Sheet 1 of 4

The VFO

big diagram

The VFO
The same type of VFO is used in the new shortwave receiver, so the story is almost the same.
Many small tuning ranges (37.9 kHz at 10 kHz and 61.7 kHz at 30 MHz) can be tuned by the 10 turn potmeter. Press the up/down switches to go to the nearest next small tuning range. For large frequency changes, set S1 to coarse tuning. Otherwise you have to press the up switch 1000 times to go from 10 kHz to 30 MHz!!
The system is based on a frequency locking system with a sampler with a VCO (Voltage Controlled Oscillator) and a VXO (Variable Xtal Oscillator). Harmonics of the (VCO/16384) are locked to the VXO. The VCO runs from 48 to 78 MHz and the VXO frequency is 10 MHz. Frequency variation of the VXO is 7.9 kHz. If you want to calculate the tuning range, the formula is:

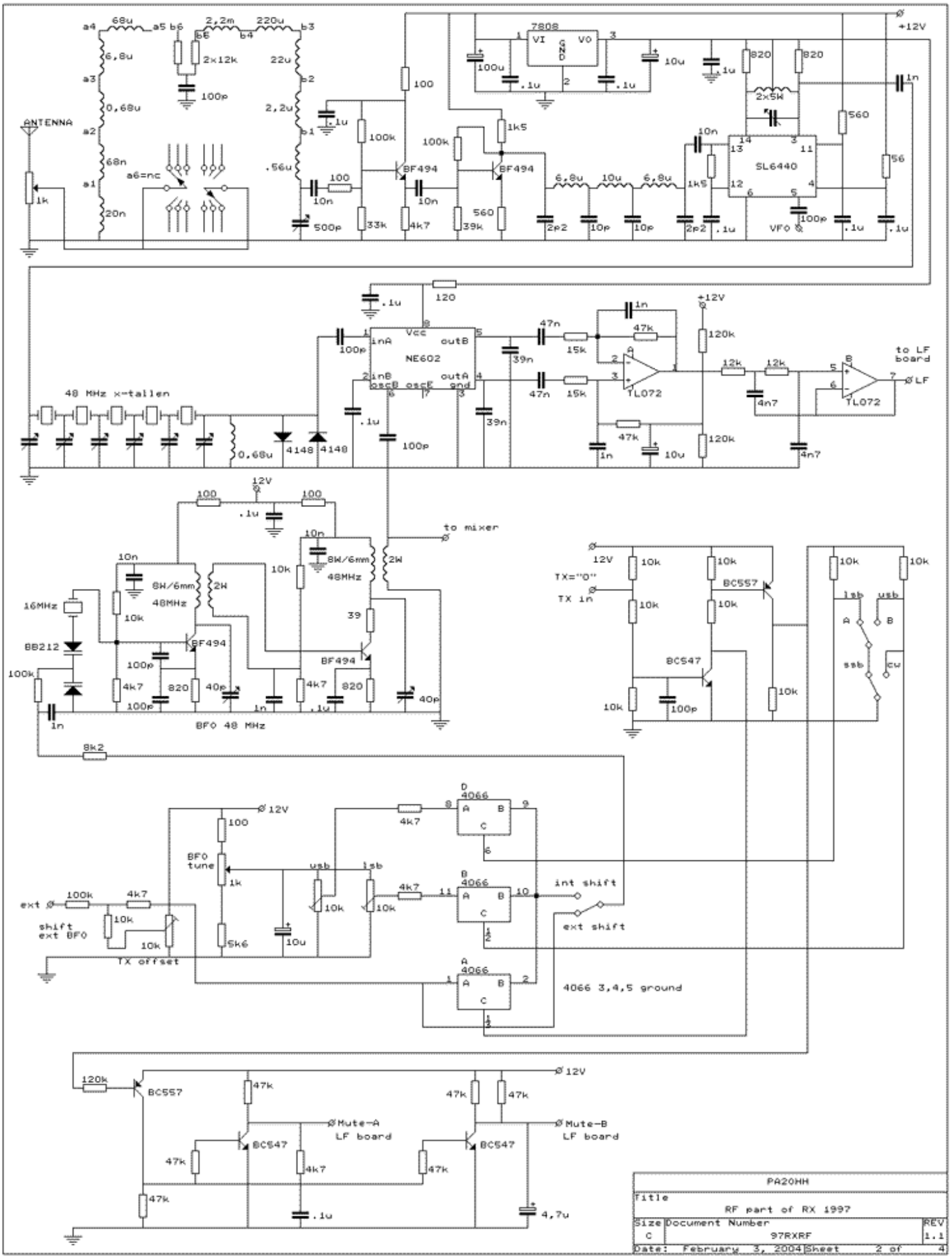
(VCO frequency) x (frequency variation of the VXO) / (VXO frequency)

So the actual frequency band that can be tuned by the 10 turn potentiometer is depending on the VCO frequency and the frequency variation of the VXO .
No ceramic resonator is used in the VXO as is in the "MyTRX" transceiver but a Xtal for better stability. Stability with a ceramic resonator is not sufficient for this design. In the MyTRX the VCO frequency is divided, giving better stability of the final frequency.
The VCO frequency is divided by 16384. The maximum frequency (here 4761 Hz) has to be less than the 7.9 kHz frequency variation of the VXO. The loop filter component values are experimentally determined. Adjustment of the loop potentiometers is done by ear. Tune to a strong carrier at a low VCO frequency and adjust the 100 ohm potentiometer by ear for the best distortion free audio tone. Even very small instabilities in the loop that are not noticed with the oscilloscope are heard by ear when tuning to a strong signal.

The VFO coil
The coil is wound on a piece of a plastic potentiometer axis. It is totally glued in plastic with a glue gun to avoid all kinds of noises when knocking against the enclosure of the receiver. How funny it was to see that the VFO stayed exactly on frequency while the hot plastic of the glue gun was cooling off!!! Normally my VFO's start drifting already at the slightest temperature changes....

Up-down switches.
One important remark about that: The Up switch does only work properly if the VXO is tuned to a high frequency. For the lower VCO frequencies it works already when the VXO is tuned to its center frequency. And for the Down switch it is just the opposite.
Sometimes a (not very stable) locking occurs while there is an AC ripple on the loop (check with an oscilloscope on TP2). But you can solve this problem with some DC offset, adjust the 10k potentiometer a little to get this DC offset.

The RF part


ANTENNA
7808
VI
VO
GND
+12V
SL6440
VFO
NE602
inA
inB
outA
outB
Vcc
osc
gnd
48 MHz x-tallen
4148
TL072
to LF board
to mixer
BF494
BB212
16MHz
48MHz
BFO 48 MHz
BC557
BC547
TX="0"
TX in
BFO tune
shift ext BFO
TX offset
ext shift
int shift
4066
4066 3,4,5 ground
usb
lsb
ssb
cw
Mute-A
LF board
Mute-B
LF board
PA2OHH
RF part of RX 1997
97RXRF
February 3, 2004
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The RF part.

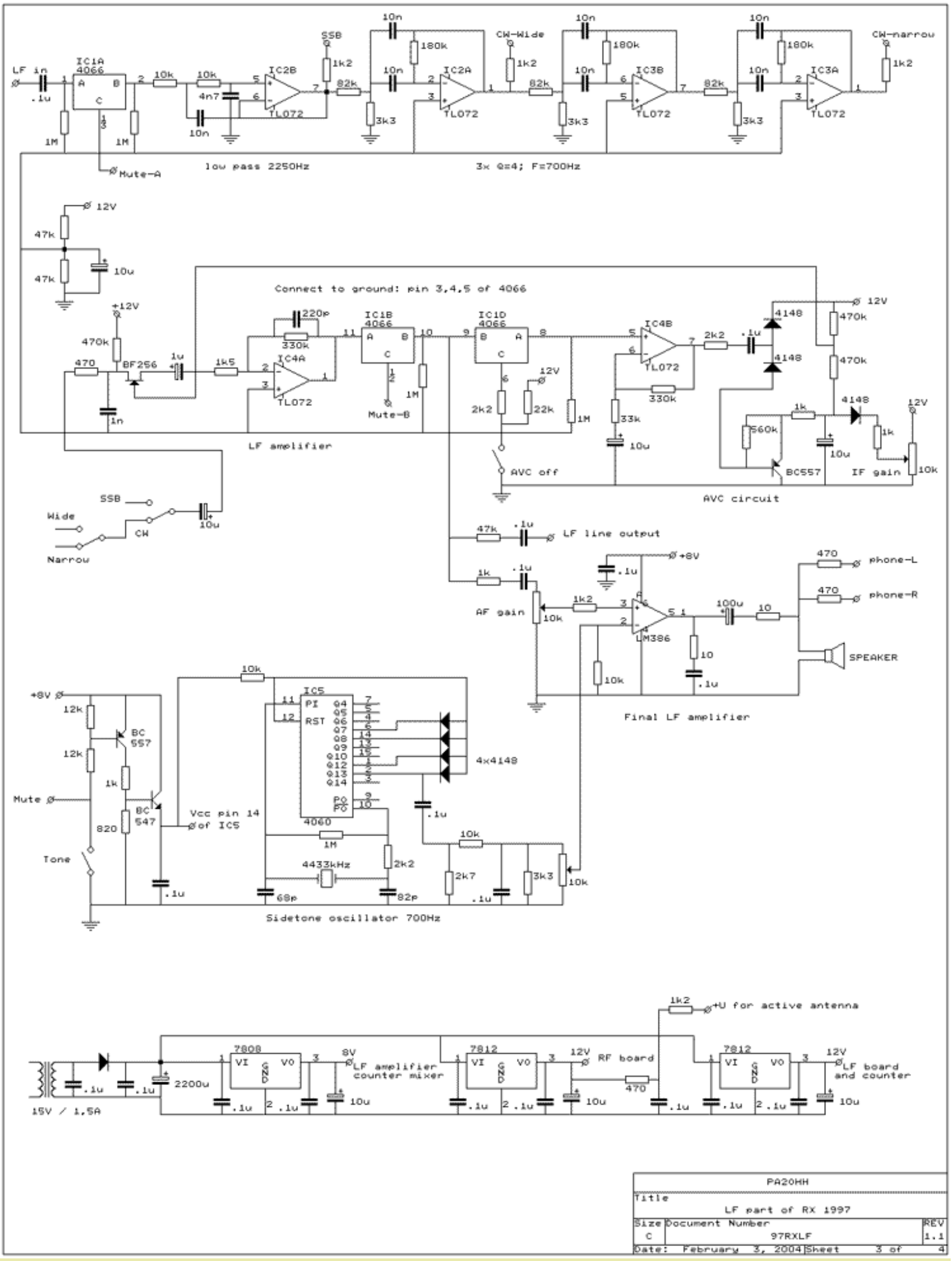
big diagram

Attenuator, preselector and HF preamplifier
Instead of broadband input filters, a tuned selective preselector is applied. The inductances are readily available parts and mounted directly on the bandswitch. For the band below 150 kHz there is a simple RC low pass filter. The first transistor of the RF preamplifier is an impedance match, the second one gives some extra gain. The gain can be varied by changing the 560 ohm emitter resistor.

The mixer
The mixer is a Winner! The SL6440 is very good. During tests of the prototype, 5 meters of wire was connected directly to the input of the mixer without any preselection and many 80 meter amateur stations could be received without any overload or intermodulation products!

The IF and BFO
A 5 pole IF ladder filter (3.5 kHz wide but I will retune it to 2.4 kHz soon) is followed by a NE612 BFO mixer. So there is no IF amplifier! I did spent a lot of time to try to make a VXO with an overtone crystal at 48 MHz, but without success.... That is why the BFO works at 16 MHz and is tripled to 48 MHz. The LC circuit in the collector is already tuned to 48 MHz. So the second transistor is not a tripler but an amplifier.
The IF gain control is not really an IF control as it is in the LF part of the receiver. But it has the same effect: Control the AVC voltage.

The LF part

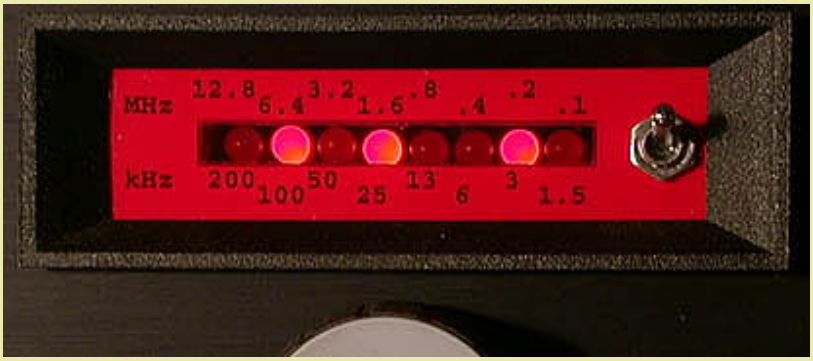


The audio part

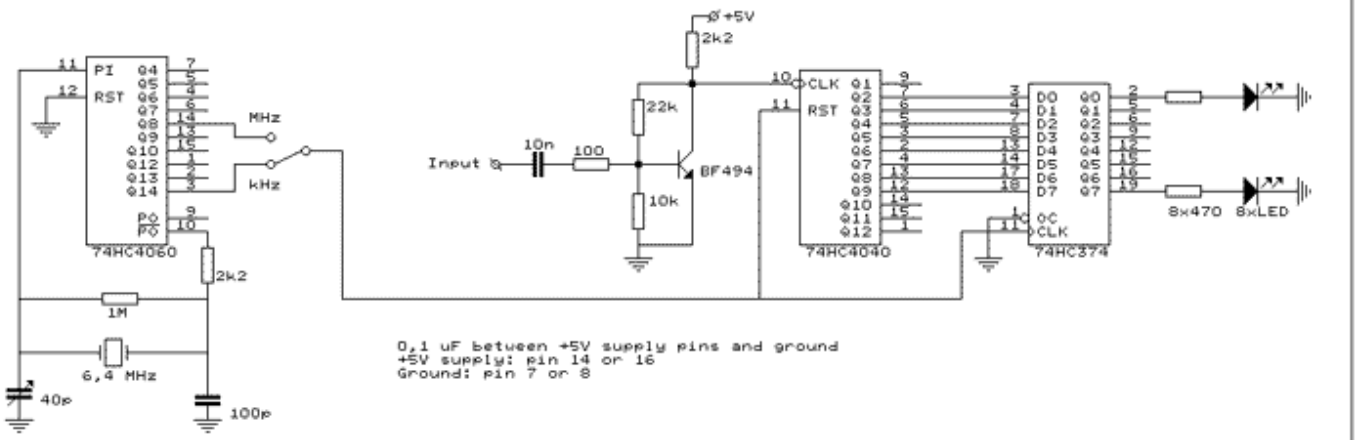
The audio part.
big diagram

The Audio part
At the input is a second SSB audio filter for extra selectivity, it attenuates the high audio frequencies as the crystal filter is quite broad. Tune it narrower will be one of the next modifications.
For CW or digital modes like Hell, there are two filtes, a narrow and a wide one.
The AVC is controlled by a fet in the LF part of the receiver. For muting there are a few 4066 CMOS switches. However, I never used the receiver in combination with a transmitter so I cannot guarantee that it works!
The side tone oscillator was an experiment, it gives an audio tone of exactly 700 Hz, that is also the center frequency of the CW filters.

The Frequency counter

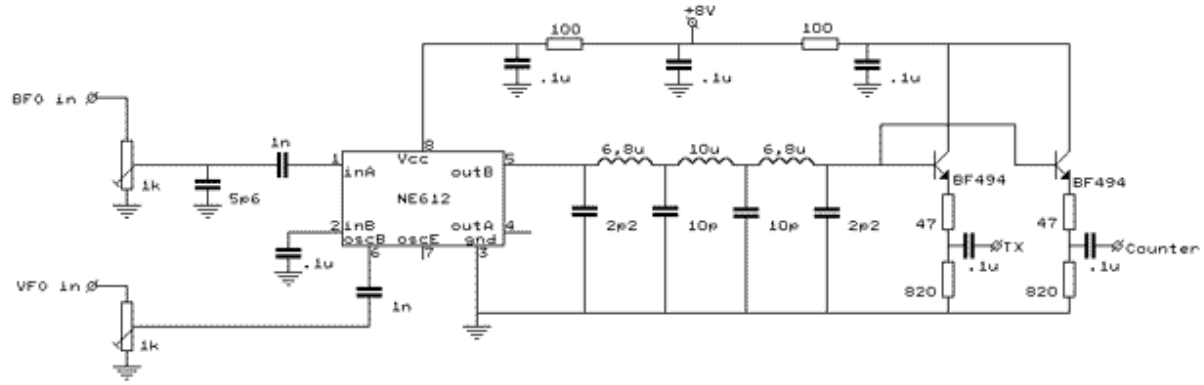


Frequency counter with 8 leds.



LED scale:

MHz	12,8	6,4	3,2	1,6	0,8	0,4	0,2	0,1
O	O	O	O	O	O	O	O	O
kHz	200	100	50	25	13	6	3	1,5



PA2OHH		
Title: Counter + counter mixer of RX 1997		
Size: C	Document Number: 97RXVF0	REV: 1.1
Date: February 3, 2004	Sheet 4 of 4	

The Frequency Counter and mixer VFO-BFO

The Frequency Counter and mixer VFO-BFO.
big diagram

The Simple Frequency counter
The idea was to have a binary display with 8 leds. The frequency can be found by adding the frequency values of the illuminated leds. With the switch in the kHz position, the frequencies of the leds D7 to D0 are rounded off to:

200 kHz - 100 kHz - 50 kHz - 25 kHz - 13 kHz - 6 kHz - 3 kHz - 1.5 kHz.

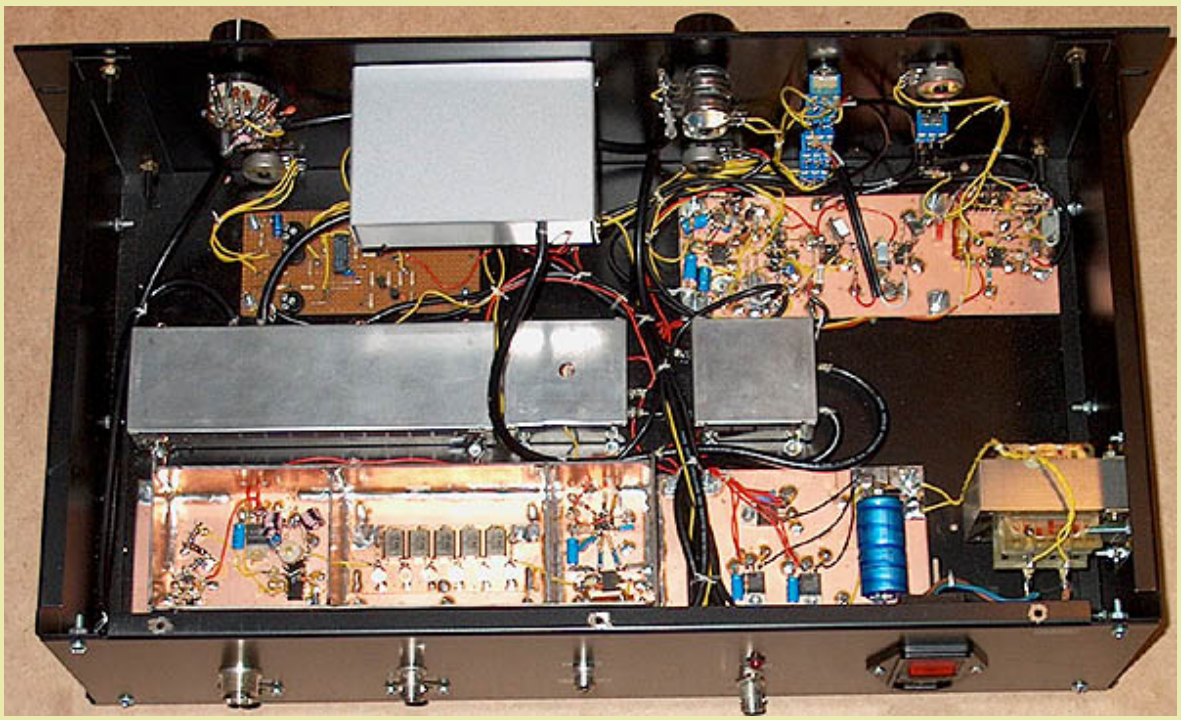
Example: Leds D7, D5, D3 and D0 are on: 200 + 50 + 13+1.5 = 264.5 kHz.
However, we want to measure frequencies that are higher than 400 kHz. Therefore, a switch is added so that the led frequencies are higher if the switch is in the MHz position:

12.8 MHz - 6.4 MHz - 3.2 MHz - 1.6 MHz - 0.8 MHz - 0.4 MHz - 0.2 MHz - 0.1 MHz.

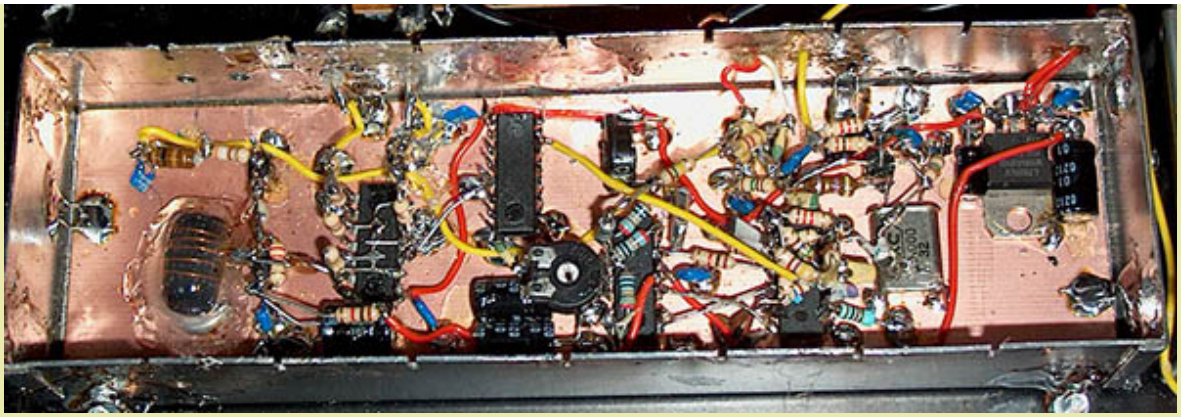
The MHz position is not so easy to use, but normally you will use it only to find the desired amateur band. Then you do use only the kHz position, reading the frequency is easy then.
The maximum frequency is 25.5 MHz (all MHz leds on). At 25.6 MHz, all MHz leds are off just as at 0 MHz. 28 MHz is displayed as 2.4 MHz. In practice, that is not a problem. A list of which MHz leds are "on" for a certain amateur band may be useful in the beginning.

The mixer for the Frequency counter
To get a signal equal to the reception frequency for the frequency counter, a mixer is used to mix the VFO and BFO down to the reception frequency. The mixer is followed by a 30 MHz low pass filter. The VFO potentiometer is set to maximum in my version, the potentiometer connected to the 48 MHz is set to a compromise between output signal and spurious. If the spurious is too high, the frequency counter does display random frequencies.

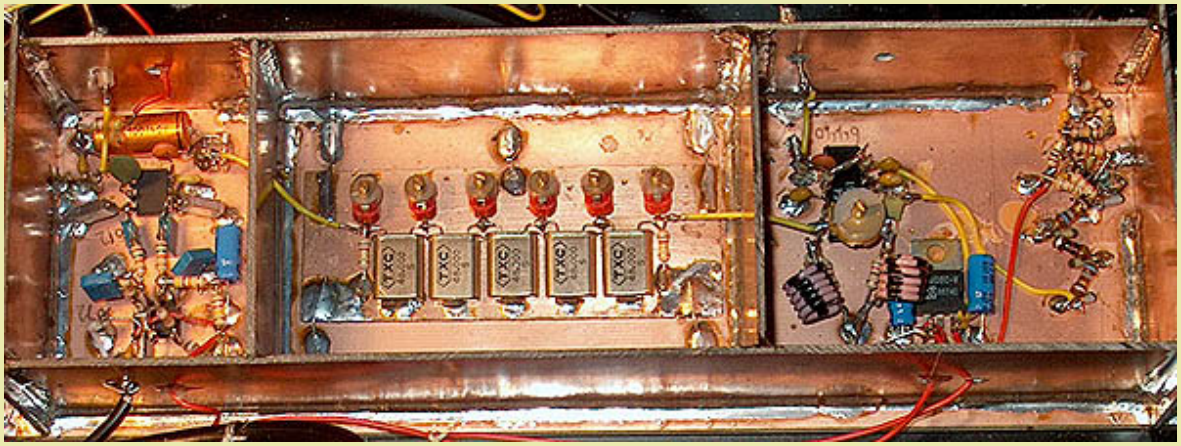
PHOTOGRAPHS



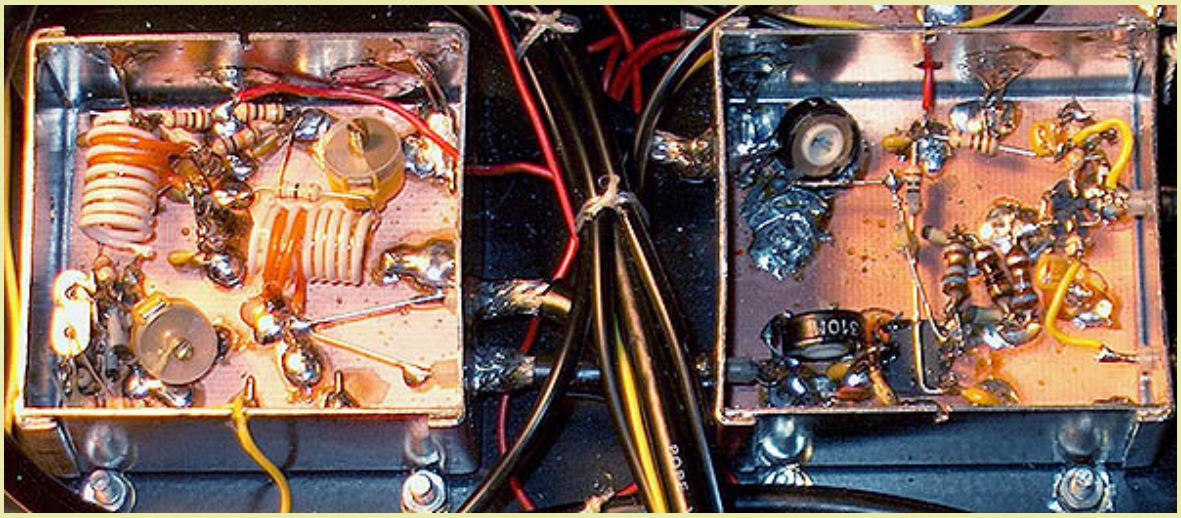
Interior of the receiver.



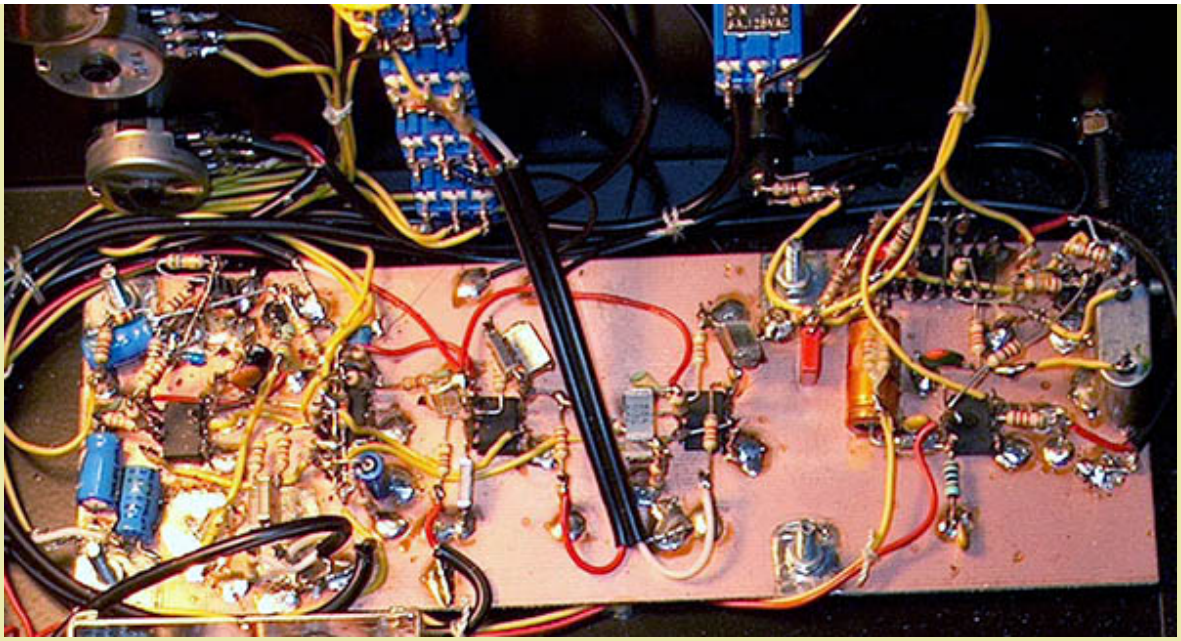
VFO 48 - 78 MHz with stabilizer.



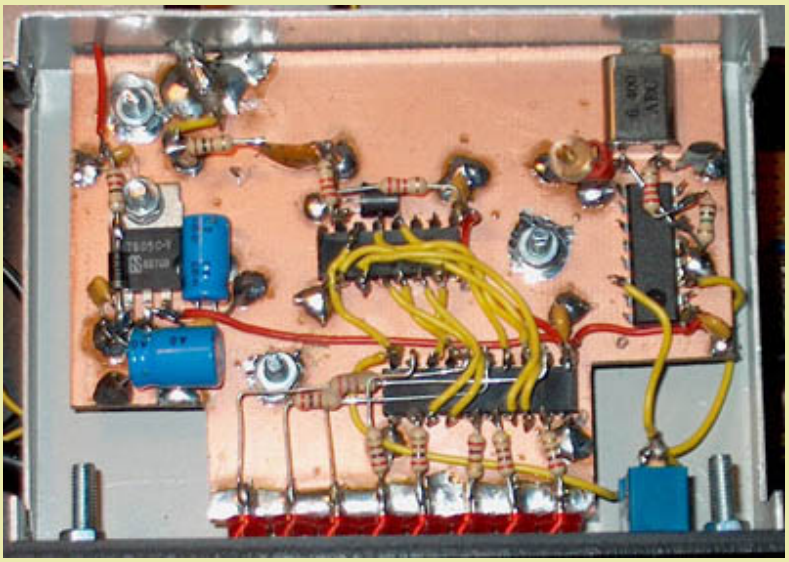
RF part with 48 MHz crystal ladder filter.



BFO 48 MHz and mixer VFO-BFO for frequency counter.



LF part with CW filters and side tone oscillator 700 Hz.



The simple frequency counter with 8 leds.

Results

It is a nice receiver with a pleasant sound. Due to the very good SL6440 mixer, the 3rd IP is approximately +8 dBm, strong signals are not really a problem! The narrow CW filter is very good for the suppression of broadband and narrow band interference. Of course it does not have all the features of a good commercial receiver, there is for example no Noise Blanker or Notch filter. But I had a lot of fun with this receiver, know how it works, can repair everything, it is easy to make modifications and finally, the second output of the mixer for the counter can be used as a signal generator from 0 to 30 MHz (but it is not spurious free enough for a transmitter as it was intended for!).

BACK TO INDEX PA2OHH

Understanding Antennas For The Non-Technical Ham

A Book By Jim Abercrombie, N4JA
(Jim Abercrombie n4ja@prtcnet.com)

Illustrations by Frank Wamsley, K4EFW

Edited by Judy Haynes, KC4NOR

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Edited for the web , N4UJW

Editors Note: This is a book length web article provided by the author FREE for all hams.
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It is HUGE!

Bookmark this page for future reading or see more options for saving at bottom of page!
The original book contained 60 pages and illustrations.
They are all here!
Many of the antennas described here are in project form on this web site.

Here are some of the main topics in the book that you will learn more about.

Antenna systems, antennas, simple antenna formulas, basic antenna theory, feed-lines, matching units, how antennas work, polarization of electromagnetic waves, frequency, the ionosphere and modes of propagation, Ground-Wave Propagation, Direct Wave or Line of Sight Propagation, Propagation by Refraction,

Skywave Propagation, Greyline Propagation, Long Path Propagation, ham bands propagation, antenna myths, standing wave ratio, real antenna systems, Flat Top Dipole, Inverted-V Dipole, Dipole Shape Variations, Calculating the Length of a Half-Wave Resonant Dipole, The Decibel, Resistances and Reactance, Feeding Dipoles Efficiently,

Cause of Feed-Line Radiation, Baluns, Other types of dipoles, Shortened Loaded Dipole,

All Band Dipoles, Sloping Dipole, Folded Dipole, Double Bazooka Dipole, Broad-Banded Coax-Fed Fan Dipole, Two-Element Collinear Dipole, Four-Element Collinear Dipole, Coax-Fed Dipoles Operated on Odd Harmonic Frequencies, Three Half-wave Dipole, All Band Random Length Dipole, All Band Center-Fed Random Length Dipole,

A Two-Band Fan Dipole, Trapped Dipole for 75 and 40 Meters, The Extended Double Zepp Dipole, The G5RV Dipole, Off-Center Fed Dipoles, One wavelength Off-Center Fed Dipole, Carolina Windom, Windom Dipole (Fritzel Type), End-Fed Antennas, End-Fed Zepp, Alternate Method of Feeding an End-Fed Zepp, End-Fed Random Length Antenna, The Half-Sloper antenna, Vertical antennas, Ground Mounted Trapped Verticals, Disadvantages of Using Quarter-Wave Verticals, Long and Short Verticals,

Unscientific Observations of Verticals, The Inverted-L Vertical , Vertical Mobile Antennas, HF mobile antenna comparisons, One wave-length single loop antennas, Horizontally Oriented Loop, Vertically Oriented Single Loop for 40 and 80 Meters,

Single-Element Vertical Delta Loop, Directional beam antennas, Monoband Yagi, Three-Element Yagi,

Trapped Multi-band Yagis, SteppIR Antenna, The Log-Periodic Array,

Directional Cubical Quad and Delta Loop Antennas, Single Band Cubical Quad, field-strength meter, The Quagi, Gain vs front to back radio, Feed lines, Antenna Safety,

Erecting Antennas on Masts, Tower Safety, Quarter Wave Matching Sections of 70-ohm Coax chart, and much more!

The Book Starts Here!
Enjoy!

PREFACE

One reason for writing this book is to educate you so you can make an informed choice concerning the best antenna for you. Another reason is to dispel the many antenna myths that circulate in the amateur community. The third reason is a desire to teach basic antenna theory to the average ham. Therefore, to achieve that goal, you should read this book from cover to cover. It was written primarily for the newcomer and the non-technical old-timer.

This book is about common medium wave and high frequency (short wave) antennas, but the theory presented here relates to antennas of any frequency. It is in a condensed form and the antenna theory is explained so most hams can understand it. Realizing many hams are mathematically challenged, only simple mathematics procedures are used. If you can add, subtract, and divide using a calculator, you will not have trouble with this book.

A few principles in here are based on conclusions drawn from the Laws of Physics. Everything else in this book can be found scattered through The A.R.R.L. Antenna Book and nothing in here contradicts what is written there.

I. WHY ALL THE FUSS ABOUT ANTENNAS

Definition: An antenna is a piece of metal, a conductor of electricity, to which you connect the radio. It radiates your signal and receives the signals you want to hear.

Definition: An antenna system consists of the antenna, the feed-line, and any matching unit. Most antennas are made of copper or aluminum, while most mobile antennas are made of stainless steel. A feed-line consists of two conductors that carry the signal to and from the radio and to and from the antenna. A matching unit can be an antenna tuner, a series matching section, or one of several different kinds of matching circuits at the feed-point.

Does the type of antenna make much difference? Here is an example: Once in 1959 two of us were involved in testing two antennas on 15 meters. The late R. Lynn Kalmbach, W4IW, using one antenna received a 30-dB better signal report on his antenna from a station in England than we did on our antenna. (Decibel or dB will be explained later). Thirty dB means his signal appeared that he was running 1000 times more transmitter power than we were. At that time, we didnt live that far apart so we couldnt blame it on propagation. We both were running about equal power. Both antennas were at

50 feet. The comparison proved that a good antenna could make a difference. Lynn used a home-built G4 ZU mini-beam; we were using a 15-meter 2-element Mosely Mini-Beam, which had short loaded elements. Evidently, it had a lot of loss.

Another example: Today we hear people breaking in to our ragchews with signals almost level with the noise. Why is that? The reason is they are using the wrong antennas. Their signals are twenty to thirty decibels below everyone elses. They are making contacts, but just barely. The first question our group asks, "What kind of antenna are you using?" Experienced amateurs know the antenna can make all the difference. The guy with the poor signal sometimes will blame his bad signal report on band conditions or his lack of a linear amplifier. He is just sticking his head in the sand.

What we are trying to prove is next to your radio, the most important part of your station is the antenna. Many years ago, an old-timer said, "For every dollar you spend on a radio, you should spend two dollars on your antenna." That is also true today. You can do more to improve your signal strength with antennas than you can ever do by increasing your power. Having the ability to make contacts on a particular antenna doesnt mean it works well! Any antenna will make contacts, but your signals will be stronger on some antennas than on others. In addition, some antennas hear better than others.

II. HOW ANTENNAS WORK.

First of all to work properly the antenna system must be matched to the transmitter. That is, all modern transmitters have an output impedance of 50 ohms. Antenna systems range in impedance of a few ohms to several thousand ohms. There are several ways to match them: pruning the length of the antenna, using an antenna tuner, matching the antenna with a length of transmission line called a matching section, or the use one of several matching systems at the antenna feed-point. Antenna matching is beyond the scope of the material found in this book and it is suggested you consult a more comprehensive antenna manual. Simple half-wave dipoles eliminate the need for a matching system because a resonant half-wave dipole has an impedance near 50-ohms.

You must understand electromagnetism to understand how antennas work. If you attach the two poles of a direct current (DC) voltage source to the two ends of a coil of wire, current will flow through the coil of wire and it will become magnetized. The magnetized coil is known as an electromagnet. Its magnetism will extend out to infinity becoming weaker with distance. Remove the voltage and the magnetic field collapses back into the coil. If an alternating current (AC) is connected to the coil, the magnetism moves out and collapses into the coil in step with the frequency of the alternating current source. The north and south poles of the electromagnet reverse on each half-cycle of the AC voltage.

If voltage and current can cause a coil to become magnetized, the reverse is true: A magnetic field can produce a voltage and a current in a coil. This is known as Faradays Principle of Magnetic Induction. A voltage will be produced at the ends of the coil of wire as you move any permanent magnet close to and parallel to the coil. The difference in this case is the magnet must be kept moving. Move the magnet in one direction, and current will flow in one direction. Reverse the direction the magnet is moving and the current will flow in the opposite direction. Moving the magnet back and forth produces alternating current. An AC generator spins a coil of wire between the two poles of a magnetic field. It doesnt matter which one is moving. The coil or the magnet can be moving. Any moving magnetic field can induce current in anther coil. It doesnt have to be a piece of metal we call a magnet. Imagine a moving magnetic field produced by AC circulating in and out of a coil. If that moving magnetic field passes through a second nearby coil, it will induce an alternating current in the second coil. A transformer uses this method to work. Transformers have a continuous iron core running from the inside of one coil through the inside of the second coil to confine the magnetism inside the iron core. This makes the transformer nearly 100% efficient since only a little of the magnetic energy escapes.

A straight wire that has an AC current flowing through it also has a magnetic field surrounding it. But it is a weaker field than is produced by a coil. The magnetic field from the wire radiates out into space and becomes weaker with distance. The radiating magnetic field from a wire is known as "electromagnetic radiation" and a radio wave is one type of it. The wire that radiates becomes the transmitting antenna. Some distance away, a second wire in the path of these waves has current induced into it by the passing electromagnetic waves. This second wire will be the receiving antenna. The voltage in the receiving antenna is many times weaker than the voltage in the transmitting antenna. It may be as weak as one-millionth of a volt or less and still be useful. The receiving antenna feeds that voltage to the amplifiers in the receiver front-end where it is amplified many thousands or millions of times.

The dipole antenna is made of a wire broken in the center and where broken, each half of the wire connects to an insulator that divides the wire in two. Two wires from the voltage source, which is the transmitter, are connected across the insulator. On one side of the dipole, the current in the form of moving electrons flows first from the voltage source toward one end of the dipole. At the end, it reflects toward the voltage source. The same thing occurs on the other half of the wire on the other half cycle of alternating current. An antenna that is the right length for the current to reach the far end of the wire just as the polarity changes is said to be resonant. Because electricity travels at 95% the speed of light in a wire, the number of times the polarity changes in one second (frequency) determines how long the wire has to be in order to be resonant.

III. POLARIZATION OF ELECTROMAGNETIC WAVES

Electromagnetic waves travel away from the wire in horizontal, vertical, slanted, or circular waves. If the antenna wire runs horizontal or parallel to the earth, the radiation will be horizontally polarized. A wire or conductor that runs at right angles to the earth produces vertical radiation. A slanted wire has components of both horizontal and vertical radiation. Crossed wires connected by proper phasing lines that shift the phase from one wire to the other wire by 90 degrees will produce circular polarization. Amateurs working orbiting satellites at VHF, UHF, and microwave frequencies use circular polarization.

When your high frequency signals are reflecting off the ionosphere, it isnt important if the other stations antenna has the opposite polarization from yours (the polarization does matter for line of sight communication). The reflected polarized waves passing through the ionosphere are slowly rotated causing fading signals (QSB). The reason the polarization of antennas is most important is that it determines the angle of radiation. Horizontally polarized antennas at ordinary heights used by hams produce mostly high angle radiation and weaker low angle radiation, but this doesnt mean there is no low angle radiation. It is there but is weaker than high angle radiation. However, you must put a horizontally polarized antenna up more than one-wavelength high to get a strong low angle radiation. One wavelength is 280 feet on 80 meters, 140 feet on 40 meters, and 70 feet on 20 meters. High angle radiation works nearby stations best and low angle radiation works distant stations (DX) best. A vertically polarized antenna produces mostly low angle radiation, with its high angle radiation being weak. For this reason, vertical antennas do not work as well as horizontal antennas do at ordinary heights for working stations less than about 500 miles away.

FREQUENCY

The number of times the polarity of an AC voltage changes per second determines its frequency. Frequency is measured in cycles per second or Hertz (Hz). A thousand cycles per second is a kilohertz (kHz). One million hertz is a Megahertz (MHz). The only difference between the 60 Hz electric power in your house and radio frequencies (RF) is the frequency, but 60 Hz electricity in a wire also produces electromagnetic radiation just like radio waves. Useful radio waves start at 30 kHz and go upward in

frequency until you reach the infrared light waves. Light is the same kind of waves as RF except light is at a much higher frequency. Light waves are used like radio waves when they are confined inside fiber optic cable. Above the frequencies of light are found x-rays and gamma rays.

The radio bands: The Long Wave Band (LW) starts at 30 kHz and goes to 300 kHz. The Medium Wave Band (MW) is from 300 kHz to 3000 kHz or 3 MHz. The High Frequency Band (HF) is from 3 MHz to 30 MHz. The Very High Frequency Band (VHF) is from 30 MHz to 300 MHz. The Ultra-High Frequency Band (UHF) is from 300 MHz to 3000 MHz or 3 GHz. Above these frequencies are several microwave bands which are defined as the Super High Frequency Band (SHF).

V. THE IONOSPHERE AND MODES OF HF PROPAGATION

The Ionosphere

In the upper air around fifty miles and higher where the air molecules are far apart, radiation from the sun strips electrons from oxygen molecules causing the molecules to become ionized forming the ionosphere. The ionized oxygen molecules and its free electrons float in space forming radio-reflecting layers. Ionization of the ionosphere varies by the time of day, seasons of the year, and the sunspot cycle. The strength of ionization also varies from day to day and hour to hour. Since the height of the ionosphere varies, the higher the ionized layer becomes, the farther the skip will be. We will define skip in section 5 of part V.

The part of the earths atmosphere called the ionosphere is divided into three layers. The three layers are, from lowest to highest, the D layer, the E layer, and the F layer. Each layer has a different effect on HF radio propagation.

Being at a lower altitude, the D layer molecules are squeezed closer together by gravity than those in higher layers, and the free electrons reattach to the molecules easily. The D layer requires constant radiation from the sun to maintain its ionization. Radio waves at lower frequencies such as the frequencies of the AM broadcast band cannot penetrate this layer and are absorbed. The higher frequency signals are able to pass through the D layer. The D layer disappears at night causing AM broadcast stations to reflect from the higher layers. This is why AM broadcast signals only propagate by ground wave in the daytime and they can be received from great distances at night. Like the broadcast band, the D layer absorbs signals on 160 and to a lesser extent 80 meters during the day making those bands go dead. During solar flares, the D layer becomes ionized so strongly that all high frequency radio waves are absorbed, causing a radio blackout.

E-layer propagation is not well understood. Being at a lower altitude than F layer, the E layer is responsible for summertime short skip propagation on the higher high frequency bands. The skip zone is around 1000 miles, but at times when the E-cloud covers a wide area in the summer, double hops can be seen. A double hop occurs when the signal reflects from the ionosphere, then returns to the ground, reflects from the ground back to the ionosphere where it is reflected back to the ground. A double hop can propagate the signal 2000 miles or more. The E-layer forms mostly during the day, and it has the highest degree of ionization at noon. The E layer like the D layer disappears at night. Even so, sporadic-E propagation can and does form at night. There is a minor occurrence of sporadic E propagation during the wintertime. On rare occasions, sporadic E propagation can surprise you by occurring anytime regardless of the sunspot cycle or the season of the year.

The F layer is the highest layer and it is divided into two levels: F1 and F2. At night the F1 and F2 merge into one layer. During the day, the F1 layer doesnt play a part in radio propagation, but F2 does. It is responsible for most high-frequency long distance propagation on 20 meters and above. However, the F

layer makes it possible for you to work DX on the lower bands at night. Sunspots are responsible for the ionization layers and in years with high sunspot numbers, worldwide contacts can be made easily on 10-20 meters by F2 layer propagation. In years of low sunspot numbers, working distant stations is difficult on those bands. Consequently, ten and fifteen meters will be completely dead most days and twenty meters will go dead at night. In years of low sunspot numbers DX contacts are easily made at night on 160, 80, and 40 meters. The sunspot numbers increase and decrease in 11-year average cycles.

Since the curvature of the earth averages about 16 feet every 5 miles, an object 5 miles from you on perfectly flat earth will be 16 feet below the horizon. Because light travels in straight lines, you cannot see objects beyond the horizon. Radio waves travel in straight lines, but there are ways to get them beyond the horizon. This is referred to as propagation.

2. Ground-Wave Propagation

Ground wave works only with vertical polarization. One side of the antenna is the metal vertical radiator and the other side of the antenna is the earth ground. The surface wave in the air travels faster than the part of the wave flowing through the ground. The surface of the earth is curved like the curved part of a racetrack. On the curved track, a car on the outside of the track has to travel faster than the car on the inside lane to stay even, and the two cars travel in a curved path. Although the wave in the air travels faster than the wave on the ground, the two parts of the wave cannot be separated. Because of this, the radio wave also travels in a curved path that follows the curvature of the earth.

The AM broadcast stations use ground wave propagation during the day and skywave propagation at night. Since radio waves at lower frequencies conduct better through the ground, an AM broadcast station on 540 kHz will be many dB stronger than a station on 1600 kHz, if both run the same power. This fact is important in understanding why ground mounted verticals do not work as well at high frequencies as they do on the broadcast band.

3. Direct Wave or Line of Sight Propagation

Antennas located on high structures can "look" over the horizon and "see" the receiving antennas. Because refraction is involved, direct waves travel 20% farther than light waves due to scattering of radio waves by the environment. Trees and other foliage are invisible to HF radio waves. Direct wave propagation is possible at all frequencies, but this mode of propagation is seldom used on our high frequency bands, but it is the usual propagation mode used by repeaters and others on VHF and UHF. If you watch TV on an outside antenna or on a "rabbit ears antenna," you are receiving the signal by direct wave propagation.

4. Propagation by Refraction

Refraction occurs when the lower part of a wave travels slower than the top part of the wave because the wave is passing through two media. These media can be two layers of air at different temperatures or they can be air and a solid. One form of refraction is caused by a radio wave passing over a hill or ridge being bent as it passes over the obstruction. This is known as "knife edge refraction." Another form of refraction occurs when layers of air of different temperatures bend the radio waves around the horizon. This is called tropospheric ducting. This mode of propagation makes long distance contacts possible at VHF frequencies. Tropospheric ducting does occur on 10 meters and lower frequencies and is noticeable when other forms of propagation are absent. On high frequency bands, many hams mistakenly call tropospheric ducting and direct wave "ground wave."

5. Skywave Propagation

Skywave propagation occurs when radio waves are reflected from the ionosphere. Practically all HF communication is done by skywave. In the ionosphere, the waves are really refracted twice, and they just appear to be reflected. The reflections are frequency sensitive, meaning each ham band reflects differently from the others. Low frequencies, such as 80 meters, reflect mainly from the lower levels of the ionosphere and the reflected signal comes nearly straight back down. This causes 80 meters to propagate to points from local out to more than a few hundred miles in the daytime. At night, when the D layer and E layer are absent, signals striking the ionosphere at lower angles may propagate many thousands of miles on 80 meters. On the bands from 20 to 10 meters, high angle signals pass straight through the ionosphere and do not reflect back down to the nearby stations. The low angle signals on these higher bands reflect from the ionosphere near the horizon and return to the Earth some miles away. The in-between region cannot hear the transmitted signals nor can you hear signals coming from this region. The in-between region is called the "skip zone." Only when the ionosphere is weakly ionized do you have a skip zone on 80 meters.

Another interesting type of skywave propagation seen on the higher HF bands is called chordal hop propagation seen frequently in trans-equatorial (TE) propagation, which is propagation crossing the equator. When this occurs, signals entering the ionosphere are trapped inside the F2 layer then they are finally refracted back to earth across the equator thousands of miles away. There is no propagation between the signal entry point and the exit point. This is skip in the extreme. On many occasions, we have worked stations far away across the equator in the southern part of South America and stations in between could not be heard. We have frequently worked VQ9LA in the Chagos Archipelago located in the Indian Ocean. The path to The Chagos Archipelago is across Europe and the Middle East and finally across the equator to his location in the Indian Ocean. One time when he was working Europe and North America at the same time, we could not hear the European stations because our path to him was via chordal hop propagation. Another way of describing chordal hop propagation is to call it ionospheric ducting.

Skywave propagation sometimes produces an effect called "backscatter." What happens is the radio waves that strike the ionosphere, instead of only reflecting father away from the transmitting station, part of the signal reflects backwards toward the transmitting station. Stations that are too close to hear each other by direct wave can communicate by the backward reflecting waves. Both stations that communicate by backscatter must point their directional beam antennas in the same direction although their direction toward each other may be at some other azimuth. Backscatter will confuse front-to-back measurements of directional beam antennas. This is because, when you turn the back of the antenna toward the station you are hearing, you may be able to hear him on backscatter from a direction opposite from him. You will be hearing him from the ionized atmospheric cloud in the opposite direction. During intense solar magnetic storms, when aurora occurs at high latitudes, stations are able to communicate by backscatter on VHF and UHF by both stations pointing their directional beams toward the aurora. This will be due north for stations in the Northern Hemisphere and due south for stations in the Southern Hemisphere. Audio from aurora backscatter will have a "wispy" sound.

6. Greyline Propagation

Greyline propagation occurs when the sun is low in the sky near dawn or dusk, although we have seen greyline propagation occur as early as two hours before sunset or as late as two hours after sunrise. It is often used to work stations on the other side of the world on 160 and 80 meters. For example, at certain times of the year when it is approaching sunset here in the States, the sun will have just risen in Asia or Australia and vice-versa. At that time, radio waves propagate along the semidarkness path that encircles the Earth called the greyline. Both locations must be in the greyline in order to make 2-way contacts. The tilt of the Earth makes the position of the greyline change as the seasons change. Greyline propagation occurs between any two locations for a brief period of a few weeks. Afterwards, different

places fall into the greyline. For several weeks in the fall of the year, an interesting example of greyline propagation occurs in the southeastern part of the U.S. On 3915 kHz, the BBC outlet in Singapore can be heard for about an hour before sunset coming in by greyline propagation. Stations to the east hear it before we do. Stations farther to the west can hear the fading signals after it fades out here because the greyline moves as the earth rotates. For those hearing it, the signal fades in, it peaks, and it slowly fades out.

7. Long Path Propagation

Long path propagation occurs when signals propagate the long way around the world. It can occur on any band. It usually occurs from stations on the opposite side of the world from you. We have worked South Africa via long path by beaming northwest early in the morning on 20 meters. When this happens, we are working him long path through the nighttime side of the earth. Since at all times half the Earth has daytime and half the Earth has night, long path propagation is determined by whether the signal is propagated through the nighttime path or daylight path. Sometimes the daylight path will bring in stations by long path propagation and at other times the darkness path provides long path propagation. One night on 20 meters, we heard a station in India coming in short path and long path simultaneously, but the short path was stronger. At the same time, California was working India by long path and they could not hear him short path. They were working him through the daylight path, and he was stronger here on the East Coast via the nighttime path.

8. 160-Meter (1.8-2.0 MHz) Propagation

Each amateur band propagates signals differently. The 160-meter band is our only MW band and it acts similar to the broadcast band. It is primarily a nighttime and wintertime band as it suffers from high summertime static (QRN). Most hams that use this band for nearby contacts use horizontal dipoles or inverted-V antennas. Some hams use vertical antennas on this band to work distant stations (DX). These DX contacts are made in the fall and wintertime at night via F layer or greyline propagation when the static levels are low. Dipoles and inverted-V antennas do not work well for DX on this band.

9. Eighty-Meter (3.5 4.0 MHz) Propagation

The CW part of this band is called the 80-meter band and the voice part of the band is known as 75 meters. Like 160 meters, eighty meters suffers from the same QRN in the summertime. Working DX on this band is a popular avocation during the fall and winter. However, 80 meters is used primarily for working nets and ragchewing. Eighty meters is primarily a nighttime band. This band can vary from being open most of the day in years with low sunspot numbers to being closed during the middle of the day in years with many sunspots. Many DX contacts have been made using dipoles and inverted-V antennas, but a vertical with many ground radials will be better.

10. Forty-Meter (7.0-7.3 MHz) Propagation

The forty-meter band has propagation that can act like either 80 meters or 20 meters. It just depends on the stage of the sunspot cycle. During the years with high sunspot numbers, nearby contacts are possible all day. At night, the skip lengthens making contacts possible to those parts of the world where it is still dark. Working DX on 40 meters is a nighttime or greyline event. When the sunspots are low, forty meters may have long skip during the day, and nearby contacts may be impossible or they may be very weak. During the time when we suffer from low sunspot numbers, many DX contacts are made during early morning, late afternoon, and at night.

If your primary interest on forty meters is SSB, our 40-meter voice band is a broadcast band in Regions

1 and 3. Region 1 is Europe, North Asia, and Africa and Region 3 is the Pacific, Southern Asia, and Australia. The top part of 40 meters is a voice band in Region 2, which is North and South America. To work SSB on forty meters at night, you will have to find a frequency between broadcast stations. Strong broadcast stations heard at night begin to fade out slowly as the morning sun rises and moves higher in the sky. As the suns angle declines in the afternoon, the broadcast stations begin to break through the noise becoming stronger as the sun begins to set. It is only in the middle of the day when no broadcast stations are heard on forty meters.

Since DX stations in region 1 and most of region 3 can only transmit below 7100 kHz, working DX on 40-meter SSB is still possible. Stations in those regions will have to transmit below 7100 kHz. (Australian and New Zealand amateurs can operate up to 7200 kHz.) They call CQ and announce where they are listening in our voice band above 7150 kHz. This is what is called "working split."

11. Thirty-Meter (10.1-10.15) Propagation

This band has such a narrow frequency that the only modes allowed here are CW and digital modes. That means no SSB. Propagation here is much like 40 and 20 meters. Unlike 20 meters, this band stays open longer at night during years with low sunspot numbers. During the daylight hours, it has much shorter skip than 20 meters. In the United States, we are allowed only 250 Watts.

12. Twenty-Meter (14.0-14.35 MHz) Propagation

The twenty-meter band is the best DX band because it is open for long-skip for more hours than any other band and it does not suffer from QRN as the lower bands. In years of high sunspot numbers, short-skip and long-distance DX can be worked at the same time during daylight hours. Although DX is there most of the time, most of the DX worked is at sunrise, sunset, and all night during peak sunspot years. During the years of low sunspots, it is common to work into Europe and Africa during the day and into Asia and the South Pacific during the evening hours and early at night. Low sunspot numbers cause 20 meters to go dead for east to west contacts at night an hour or so after sunset, but there is some TE propagation. During periods of moderate sunspot numbers, the propagation on this band is a blend of propagation of low and high sunspot years.

13. Seventeen-Meter (18.067-18.167 MHz) Propagation

The 17-meter band propagation acts much like 20 meters except it is affected more by low sunspot numbers than 20 meters. In periods of low sunspot numbers, this band does not stay open as late as 20 meters, fading out as the sun begins to set. Yet, the 17-meter band does stay open all night when the sunspot numbers are high. The propagation on this band is like a blend of 20 meters and 15 meters, but it is closer to 20 meters. Most users of this band use dipoles and other simple antennas since triband beam antennas wont work here.

14. Fifteen-Meter (21.0-21.45 MHz) Propagation

Fifteen meters is a fantastic DX band during the high sunspot years. This band may be open for 24 hours, and it is common to work more than 100 countries during a contest weekend on this band. Many have worked more than 300 different countries on 15 meters. In years of low sunspot numbers, 15 meters may be completely dead for several days in a row. When it opens during those years, you may hear only the Caribbean, South America, and on rare occasions the extreme southern part of Africa via TE propagation.

15. Twelve-Meter (24.89-24.99 MHz) Propagation

The 12-meter band is much like 15 meters, but it is affected more by sunspot numbers. Because this band is little used, many hours can pass without hearing any amateur signals. Occasionally you will hear South American Citizen Band "pirates" on lower sideband. It is mostly a daytime band but openings to Asia and the South Pacific are common early at night during peak sunspot years. The reason this band is little used is that triband beam antennas dont cover this band.

16. Ten-Meter (28.0-29.7 MHz) Propagation

The band that is most affected by the sunspot numbers is 10 meters. You may have noticed in this discussion, the higher the frequency, the more it is affected by sunspots. During peak sunspot years, 10 meters can be open some days for 24 hours. Mostly it is a daytime band. When they are at the peak, the sunspots enable you to work worldwide with power as low as 5 Watts. A 10-meter confirmed country total of over 250 is common. In the low sunspot years, the band can be closed for days. Ten meters can open for very short skip by sporadic E propagation during the summer months. Very short skip means contacts as close as 200 miles out to 1000 miles. Sporadic E propagation can suddenly occur without regard to the sunspot numbers.

VI. STANDING WAVE RATIO

A standing wave ratio bridge is used to measure the standing wave ratio, or SWR. SWR is an indication of how well the radiating part of an antenna is matched to its feed-line or how well the tuner is matching the antenna system. Most amateurs pay far too much attention to SWR. An SWR reading below 2:1 is acceptable, because the mismatch is so small that the feed-line loss can be ignored. If you are using a modern transceiver, its power may fold back to a lower power output above this SWR level.

When you have mismatch between the feed-line and the antenna, part of the power feeding the antenna system reflects back toward the tuner and the transmitter. The part of the power going toward the radiating part of the antenna system is called forward power. The part reflected back down the feed-line is called reflected power. The larger the mismatch the larger the reflected power will be.

If the feed-line and antenna are not matched, waves traveling toward the radiating part of the antenna system meet the waves being reflected back down the feed-line. The waves interfere with each other, and at certain points along the feed-line, the amplitudes of both waves combine. This will result in a current maximum to be found at that point; and at that point, the current will appear to be standing still. The length of feed-line and the frequency will determine where this point occurs. At another point, the forward and reflected waves interfere, and they subtract from each other. At that point, there will be a current minimum. If you could visualize this phenomenon, you would see a series of current maximums and minimums standing still along the feed-line. This is why we refer to them as standing waves. At different points along the feed-line, where you have high current, you will have low voltage, and where you have low current, you will have high voltage. At any point along the feed-line, multiplying the voltage times the current will equal the power in Watts. When the feed-line is matched to the antenna, current and voltage remain the same all along the feed-line because there is no reflected current to interfere with the forward current.

As happens with the current, the voltage will also appear to be standing still. The voltage maximums and voltage minimums will not be at the same locations as the current maximums and minimums. SWR is the ratio of the maximum voltage to the minimum voltage on the line. It is called "Voltage Standing Wave Ratio" or VSWR, but we shorten it to just SWR. There is also a current SWR or ISWR, and it is the same value as the VSWR. For example, if the standing wave voltage maximum is 200 volts and the minimum voltage is 100 volts, the VSWR will be 2:1. If the voltage maximum and voltage minimum are equal, the SWR will be 1:1. If the voltage minimum is zero, the SWR is infinite.

In measuring SWR at the transmitter, you need to realize that feed-line losses affect the SWR readings. If the feed-line losses are high, much of the power reflecting back from the antenna will be lost, and the SWR reading on the meter will indicate it is lower than it actually is. If a feed-line is so lossy that it consumes all forward and reflected power, it will measure an SWR of 1:1.

When measuring SWR on an antenna having a small amount of reflected power, the length of the feed-line between the bridge and the antenna may affect your SWR reading. An example of this is a 70-ohm antenna being fed with 50-ohm coax. Different lengths of feed-line will give you small differences in SWR readings because at certain lengths, the mismatched feed-line starts to act like a series matching section. In the case of a 70-ohm antenna fed with 50-ohm coax, if the feed-line is a half wave long, the SWR will measure 1.4:1. At some particular length of feed-line and on one frequency, the SWR will measure 1:1 because that length of that feed-line transforms the impedance to make a match. Some hams have adjusted their feed line length to get a perfect match. This is called "tuning your antenna by tuning your feed-line." With other feed-line lengths, you will measure something different. Suppose the impedance of the feed-line and the antenna are perfectly matched. Then there is no reflected power. You will get a 1:1 reading on the SWR-bridge with any length of feed-line.

There is a myth that reflected power is burned up as heat in the transmitter. The reflected power coming back down the feed-line sees an impedance mismatch at the transmitter or tuner and it reflects back up again. The reflected power does not get back into the transmitter. Because the reflected power reflects back and forth, the radiating part of the antenna system absorbs most of the power being reflected back up each time. All of it eventually is radiated except for the power lost in the feed-line. The losses in a real feed-line will burn up some of the power on each pass. This is why the feed-line loss increases with SWR.

Built-in tuners are found in most modern transceivers. If yours doesnt have one, then you can use an outboard tuner to give the transceiver a proper load. The place you want a 1:1 SWR is between the output of a transceiver and antenna or between the transceiver and the input of a tuner in order for the transmitter to deliver its maximum power. Because built-in tuners are in most modern transceivers, many hams use them to match antenna systems having high loss.

VII. REAL ANTENNA SYSTEMS

In this book, we will be talking about the losses that rob an antenna of its maximum performance. The ideal antenna system will radiate 100% of your transmitter power on all bands without a tuner and in the direction you want to work. Such an antenna system does not exist. Many new hams succumb to antenna advertisements making claims that are exaggerated. No antenna will have low SWR, work all bands without a tuner, and radiate efficiently at the same time. A dummy load has a low SWR and will load up on all bands, but it will not radiate a signal. A resonant coax-fed dipole antenna will have a low SWR and will radiate efficiently on the band for which it is resonant, but it will not work well on all bands. For example, if the tuning range of your tuner has a sufficient range, you will be able to load up any antenna with it, but it will not necessarily radiate a signal efficiently. It may have high tuner and feed-line losses.

When you choose an antenna, you must decide how much loss you can accept. DXers and hams that work weak signals at VHF frequencies try to eliminate as much loss as possible. If your contacts are going to be made under good band conditions and without much interference, you can get by with high losses. In that case, coax-fed antennas used on bands where they are not resonant will allow you to make contacts. You can be greatly surprised by how little radiated power can be used to make contacts under ideal conditions. If you want to make contacts regularly under changing band conditions, you will want to eliminate as much loss as possible and use antennas with gain. Lower loss will enable you to hear weaker signals.

Nothing will take the place of resonant half-wave dipoles, not because they radiate more efficiently, but because they dont require lossy tuners and dont have high coax losses. Remember that all antenna systems have compromises

VIII. HALF-WAVE RESONANT DIPOLE ANTENNAS

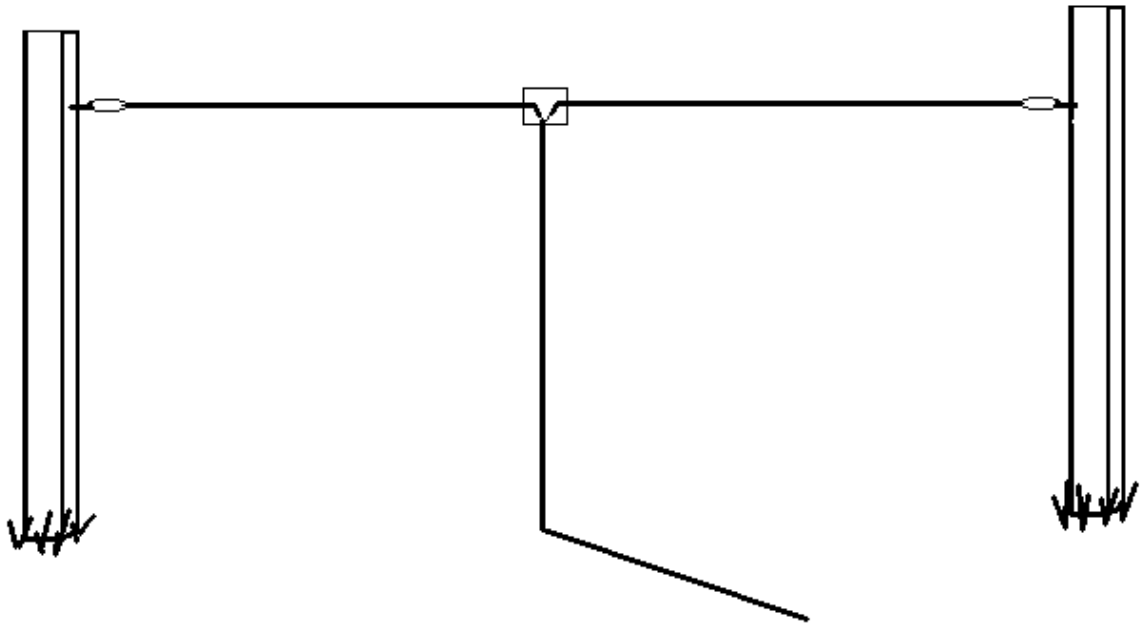
1. The Half-Wave Flat-Top Dipole

Most dipoles consist of two pieces of wire of equal lengths with one of the two ends connected together through an insulator. The far ends of the wires are also connected to insulators. The two conductors of a feed-line are separated and connected across the gap at the center insulator. The antenna is held up by rope that connects the insulated ends of the antenna to two supports. It is a "balanced" antenna, because equal currents flow on both halves of the antenna. Coax is an unbalanced feed-line. (The possible effect of using an unbalanced feed-line on a balanced antenna like a dipole will be discussed later.) The dipole that is stretched between two high supports is called a flattop dipole, distinguishing it from other configurations.

The simplest antenna system of all is the half-wave resonant dipole fed with coax and no tuner. The only reason for using a half-wave resonant dipole antenna is to eliminate the need for a matching device such as a tuner. The feed-point impedance will be near 50 ohms at ordinary heights and they can be fed directly with 50-ohm coax from the output of todays modern radios. The two halves of a dipole are fed 180 degrees out of phase, meaning when one side is fed positively, the other side is fed negatively. That is why a feed-line has two conductors. Of course, the sides swap polarity on each half cycle.

If you could visualize the current flowing on the half-wave dipole, the current will appear to be standing still. The maximum current will be seen at the center of the wire and no current will be at the ends. This occurs because the electrons flowing out to the ends reflect back toward the center where they meet the next wave and the current is reinforced there. The minimum voltage occurs at the center and the maximum voltage occurs at the ends of the half-wave resonant dipole. If you were to measure the voltage and the current at any point on the dipole wire, the voltage times the current will equal the power in Watts.

Figure 1. Flat Top Dipole



2. Inverted-V Dipole

Another configuration for the half wave resonant dipole is one having one support in the center and the ends stretched down toward the ground. The single support can be a tree, mast, or tower. The ends of a dipole have high RF voltages on them, and need to be at least 10 feet above ground for safety. This antenna is called an "inverted-V," because the shape of the dipole looks like a "V" turned upside down. Most dipoles illustrated in this book can be put up in the inverted-V configuration. This configuration works well because the current is concentrated on the middle two-thirds of the antenna at the apex. The current in an antenna is what is responsible for the radiation. The ends of the antenna have very little current in them and it doesnt matter if the ends are close to the ground. The middle of the antenna is up high where the radiation is taking place and that is the place you want the radiation to be. An inverted-V has an advantage that the horizontal space required for it is less than what is needed for a flattop dipole. The angle between the wires on an inverted-V needs to be greater than 90 degrees. The gain of an inverted -V is 0.2 dBd and it has a radiation pattern nearly omni-directional. Since it is easy to construct and works so well, the inverted-V is the most commonly used dipole. An explanation of the decibel will come later.

Figure 2. The Inverted-V Dipole

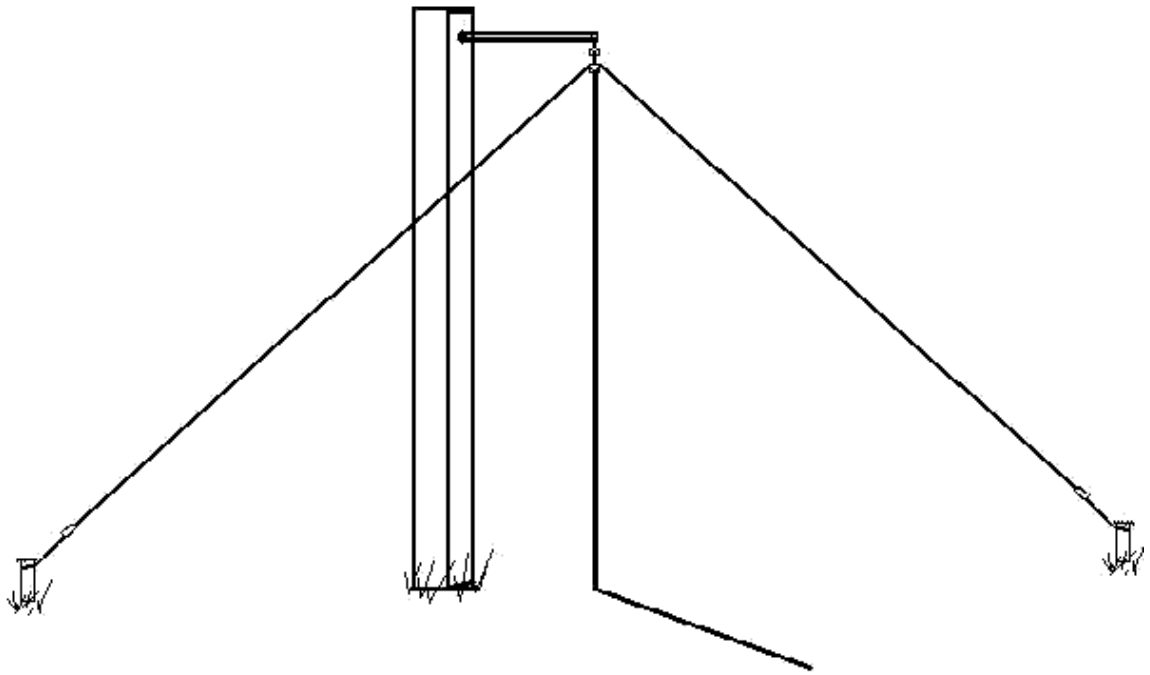
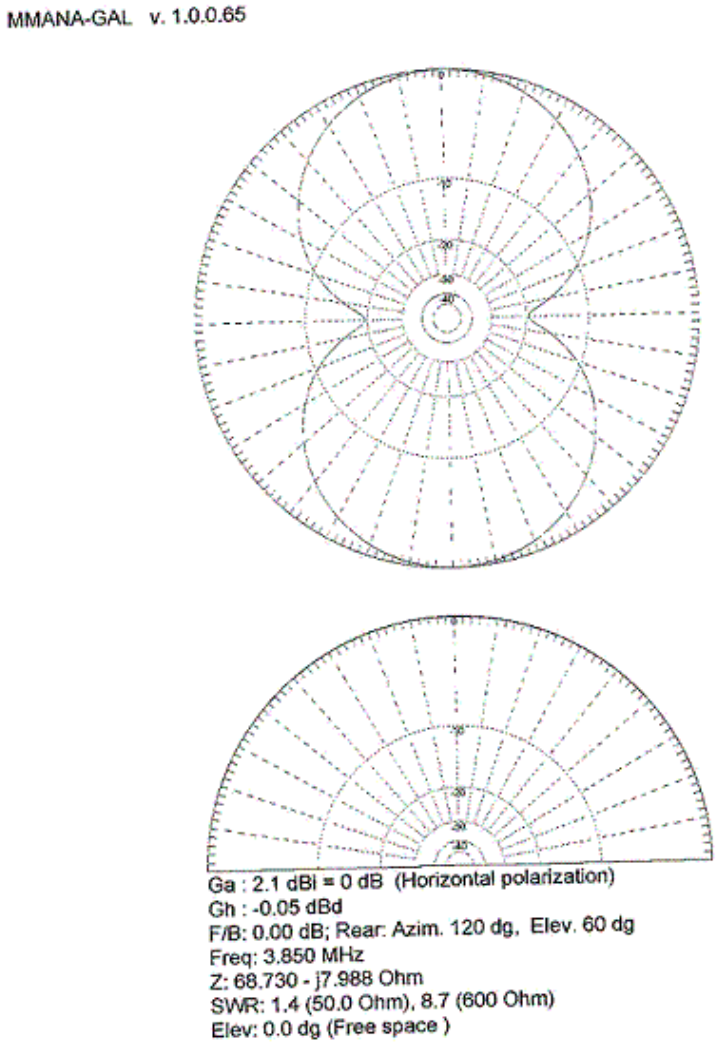


Figure 3. Radiation Pattern of Inverted-V for 80-Meters at 65 Feet



In figure 3 above, the top graph shows how the radiation would appear to you, if you were situated above the dipole and you were looking down on it. The plane of the antenna runs from side to side on the top graph, and that graph demonstrates only a 5-dB null off the ends of the antenna. Therefore, it is essentially omnidirectional. The bottom graph shows how the radiation would appear if you were looking at the antenna from the end of the wire. As you can see, the pattern shows no radiation at the horizon and its maximum radiation is at about 40 degrees above the horizon, and the radiation straight up is only down 3 dB from its maximum. This antenna was modeled on 80 meters with the apex at 65 feet above ground and the ends at 35 feet.

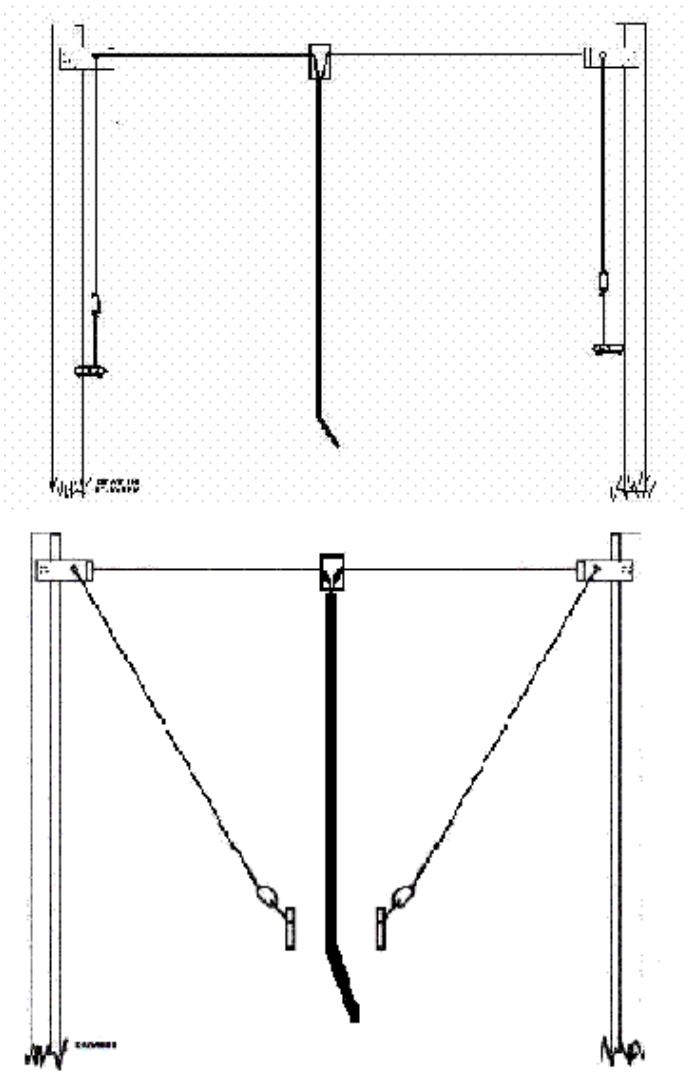
It is a myth that a horizontal antenna orientation makes a difference on 80 meters at heights used by most amateurs. I have heard many amateurs say on 80 meters, "The reason my signal is weak to you is because you are off the end of my dipole." The radiation pattern from a dipole is essentially non-directional until the dipole is elevated more than a half wave, that is about 125 feet on 80 meters, and it is 65 feet on 40 meters. The main reason it makes no difference regarding orientation is because propagation for signals closer than 500 miles (the distance of most 80 meter contacts) is essentially by

high angle radiation nearly straight up and down. Only signals radiated and received at low angles make a difference in antenna orientation even at low heights above ground. At low heights, there are nulls about 3 to 4 dB off the dipole ends.

3. Dipole Shape Variations

The wire of a dipole doesnt have to be run in a straight line. A dipole does not have to be perfectly horizontal. Thats the way it is usually depicted in books and magazines, but you can bend the legs of the antenna up, down or sideways.

Figure 4. Two Dipole Shape Variations



If you make either wire one-half wavelength long and carefully prune it to resonance, you can use it without a tuner on and near its resonant frequency. Both antennas have the current part at the top where most of the radiation takes place. The vertical parts of these antennas radiate a weak vertically polarized wave. The only reason these dipoles are contorted this way is to make them full-sized and to fit in the available space. Other shapes are possible, and you can be creative at your location.

There are many more dipoles than the ones just described. We will explore the other kinds of dipoles in section "X" of this book.

4. Calculating the Length of a Half-Wave Resonant Dipole

The approximate length in feet of a half-wave resonant dipole is found by dividing 468 by the frequency in MHz. The actual length of it will be determined by several factors. Using larger diameter wire will make the dipole resonate lower in frequency. Therefore, to make it resonant at the higher desired frequency,

It must be shortened. Raising a dipole higher above ground will make it resonate higher in frequency. An insulated wire will make the dipole resonate lower in frequency than a bare wire.

Using the above formula, cut the antenna a little longer than the calculations say. If the SWR is best at a lower frequency than you desire, the antenna will have to be made shorter by pulling the excess wire through the end insulators, folding the ends of the extra wire back on itself. Then wrap the ends of the overlapped wire on itself so it wont come loose. This causes the excess wire to "short" itself to the rest of the antenna. If you are using insulated wire, you will need to cut off the excess wire. The reverse is true if the antenna resonates too high in frequency. The extra wire can be let out to make it resonate on a lower frequency. This is why you originally cut the wire a little longer.

5. The Decibel

The decibel (dB) is a unit of measurement for comparisons of the ratio of power, current, and voltage and is the term we will use in comparing antennas in this book. At one time, antenna comparisons were made using a dipole as a standard, but today most comparisons use the isotropic radiator as a reference. An isotropic radiator is an imaginary antenna that radiates equally well in all directions. It has no gain. The terms "dBi" and "dBd" are used to label which reference is being used. In this book, we will use the dipole as a standard for the most part.

How do you derive decibels from power ratios? The formula for power ratios is dB = 10 log P1/P2. For voltage and current, the values are doubled. Formulas of this type are beyond the scope of this book. Doubling the power will produce a 3 dB stronger signal. Double the power and double it again will equal a 4 times power increase and that gives 3 dB plus 3 dB or 6 dB. Double 4 and that is a power increase of 8 and that adds 3 more dB for a total of 9 dB. Increasing the power from 1 Watt to 10 watts or increasing it 10 times will give a 10-dB increase. Multiply 10-Watts times 10 give us 100 watts, which adds another 10 dB above 1 Watt for 20 dB. Therefore, increasing the power another 10 times to 1000 Watts will produce a signal 30 dB stronger than 1 Watt.

Your receiver, if modern, will have a signal strength meter or "S Meter." That meter is calibrated in "S-Units" from one to nine and decibels over S-9. S-9 is usually calibrated using 50 microvolts (uV) from a signal generator. Each S-unit is approximately a difference of 5 or 6 dB. Therefore, a reading of S-9 is about 6 dB stronger than S-8. Therefore, from S-0 to S-9 is 54 dB. On some low cost transceivers, the S-units and dB above S-9 are only relative signal readings and actually have nothing to do with decibels.

IX. ANTENNA BASICS

1. Resistances and Reactance

Two factors measurable in antenna impedance are resistance and reactance. When we refer to antenna resistance, we are referring to its radiation resistance. It is neither a resistance like the electronic component called a "resistor," nor is it the same as the resistance found in all conductors. Those types of resistances, called "loss resistances," change electrical energy into heat energy. Heat energy disappears by radiating out into its surroundings and it dissipates away to infinity. When we feed RF into the

antenna, the energy put into the radiation resistance disappears from the antenna by radiation of electromagnetic waves, and that makes an antenna appear to have a resistor in it. Loss resistance robs power from the radiation resistance and lowers the efficiency of an antenna system, but the loss resistance in dipoles is very low if the feed-line loss is low. The efficiency of any antenna system is found from a ratio of radiation resistance and loss resistance. We can either calculate the loss resistance by the loss in the feed-line from published tables and by estimating the loss in tuning units. Feed-line loss and tuning unit loss can be measured, but that is beyond the scope of this book.

Antenna systems having reactance prevent the transmitter from delivering its full power and the reactance needs to be tuned out. There are two kinds of reactance: capacitive and inductive. Antennas have both. In antennas, reactance is a virtual reactance meaning the antenna acts as if there were a capacitor or an inductor in the antenna, but neither is there. You can only measure the sum of both reactances but not a value for either one. Using an antenna analyzer, you can determine whether the sum of the reactance is inductive or capacitive. Inductive reactance is a negative number and capacitive reactance is a positive number.

The reactance of an antenna forms the "J" factor in antenna impedance measurements. The "J" factor is measured in ohms and the reactance is expressed as + or "J" ohms depending on whether it is capacitive or inductive reactance. Capacitive reactance is expressed as +J ohms and inductive reactance is expressed as -J ohms. Capacitive and inductive reactance are opposite factors and one can cancel the other. An antenna having 6 ohms capacitive reactance or + J 6 ohms and an inductive reactance of J 5 ohms will result in an antenna with a reactance of 1 ohm capacitive or + J 1. Since one term is positive and the other term is negative, you subtract smaller value from the larger. The answer has the sign of the larger one. In antennas, the reactance and resistance together determine the overall impedance of the antenna. The J factor is mentioned here only because you may see it in other books and on the extra class examination, but it will not be used further here.

A resonant antenna has equal amounts of inductive and capacitive reactance, and the sum of the reactance equals zero. As an example, when the inductive reactance equals J 5 and the capacitive reactance equals +J 5, their sum equals zero. When the sum of the total reactance of an antenna is tuned to zero, its impedance is totally resistive. The use of an antenna analyzer will tell you if the antenna is too long or too short for resonance. The simplest way to tune out antenna reactance is to change its length. The sum of the reactance of a long antenna will be inductive, and the sum of the reactance of a short antenna will be capacitive. If an antenna is short because it wont fit your property, it can be tuned to resonance by putting an inductor (coil of wire) in each leg. These coils are called "loading coils." An equal amount of inductive reactance will cancel the excessive amount of capacitive reactance. An antenna with loading coils is described in section "X." When an antenna is too long, the sum of its reactance will be inductive, and a variable capacitor can be inserted in each leg to tune out the inductive reactance. This is seldom done because it is easier to shorten the antenna.

A resonant antenna may still have SWR if its radiation resistance is not exactly 50 ohms. Not many resonant antennas have a radiation resistance of exactly 50 ohms, and most real antennas have a small amount of SWR. An antenna is resonant only at one frequency per band. It will also be resonant on its harmonic frequencies, where its radiation resistance will range from high to very high. Hams talk about using resonant antennas. What is meant by this is they use an antenna on its fundamental frequency close to resonance, the resistance is near 50 ohms, and the SWR without a tuner is near 1:1.

To calculate the impedance of an antenna with both resistance and reactance requires a mathematical procedure called the Pythagorean Theorem. That type of math is beyond the scope of this book. However, you should know how to use the Pythagorean Theorem to solve impedance problems on the Extra-Class test. Otherwise, you will have to memorize the answers from the question pool.

2. Feeding Dipoles Efficiently

For maximum power transfer from transmitter to the antenna, the antenna system must be resonant, and the resistance of the load (antenna system) has to be equal to the internal resistance of the source (transmitter). Notice we said an antenna system, not the antenna, must be resonant. As mentioned previously, an antenna system consists of the antenna, the feed-line, and any matching networks (tuners). A tuner at the input end of the feed-line can make a non-resonant antenna system resonant, and have a resistance of 50 ohms, and that matches the internal resistance of the transmitter. A tuner will not change the SWR between the tuner and the dipole part of an antenna system, and will not remove the reactance from the dipole.

When the load of an antenna system does not match the source and the impedance is high, the load will not draw power from the source and high RF voltages will be present at the output of the final transistors. In this case, high RF voltages can damage the output transistors of the transmitter. When the impedance of the load is low, too much of the power may be dissipated across the internal resistance of the transmitter possibly destroying the output transistors. These are the two reasons why transceivers "fold back" their power when the SWR is high.

It is a myth that the dipole part of an antenna has to be resonant to be efficient. When power reaches the radiating part of the antenna system, it obeys the "The Law of Conservation of Energy." The Law of Conservation of Energy states, "Energy can neither be created nor destroyed. Only its form can be changed." (What is important is to get the power to the dipole itself, because in some systems power is lost in the feed-line, especially when using coax with high SWR) The miniscule amount of power in the dipole that does not radiate is changed into heat, another form of energy. Because the dipole part of an antenna system is made of conductors with low loss resistance, 99% or more of the power reaching it will radiate regardless of its length if that length is reasonable. The loss resistance of the conductors of the radiating part of most antenna system is so low it can be ignored. (Short mobile HF antennas are an exception because they may be lossy because of the very high current flowing in them.)

Not all the energy fed into an antenna system will reach the antenna itself. If the system has a tuner, part of the power is lost in the inductor of the tuner and part is lost in the feed-line. When properly tuned, tuners using T-networks lose about 10% of the power and L-network tuners lose about 5% of the power being fed to them. Notice we said properly tuned. However, improper tuning of the antenna tuner may cause you to believe the feed-line is matched, but when this happens there is a very high circulating current in the inductor causing it to get hot. This causes extremely high losses, and very little power reaches the radiating part of the antenna. In addition, so much heat is produced in the inductor that it can be damaged. We melted the plastic insulation that forms the inductor on one tuner this way. For this reason, some hams dont like tuners, preferring to use resonant antennas. Read the instructions for your tuner for proper tuning or you may wind up with a poor signal and a damaged tuner. The resistive losses in the conductors of the feed-line and the dielectric losses in the feed-line also rob power from the system. These are the reasons for you to use the best tuners and feed-lines possible.

Another loss to be considered is feed-line radiation. Any energy that radiates from the feed-line does not reach the radiating part of the antenna, and it may be absorbed by near-by objects and may not radiate in the desired direction. When coax radiates, it is called common-mode radiation. If the feed line can radiate, it can also receive signals. This can be detrimental because the coax can then pick up noise from near-by power lines, etc. Feed-line radiation will also destroy the directional pattern of a beam antenna. The causes of feed-line radiation will be described in the next section.

As we pointed out earlier, when you are using a half-wave resonant dipole fed with low-loss coax without using a tuner, almost all of the power coming out of the transmitter will radiate. On its resonant

frequency, the dipole is one of the most efficient antenna systems a ham can use. However, a half-wave resonant dipole has a finite bandwidth. Why use a tuner with resonant antennas? On 160 and 80 meters the bands are wide compared to the percentage of frequency. The width of 80 meters is 500 kHz and its frequency is 3500 kHz. The width of 80 meters is 14% of the frequency. The 350 kHz of 40 meters is 5% of the frequency and most of the band can be covered without a tuner. The 350 kHz width of the 20-meter band is 350 divided by 14000 kHz, or 2.5 % of the frequency, etc. The percentage of frequency for a band will determine if a resonant dipole will work the whole band without a tuner. If you are planning to move around on 160 or 80 meter bands, it makes sense to have a tuner, because the bandwidth of resonant dipoles on those two bands is narrow. For example, the normal 2:1 SWR bandwidth of an 80-meter dipole is less than 200 kHz and the band is 500 kHz wide. However, if you have an antenna resonant for the voice portion of the band, you can still use a tuner to work the CW part of the band without inducing more than a dB of loss. Except for 40 and 10 meters, full-sized resonant dipoles on the rest of the HF bands will have enough bandwidth for them to cover the whole band.

The best place to insert a tuner is up at the antenna feed-point. However, if it is placed there, you wont be able to reach the tuners controls. Therefore, it is more practical to place it between the transceiver and the shack-end of the antenna feed-line. A piece of 50-ohm coax connects the radio to the tuner. With the tuner located in the shack, adjustments can be made. Remote automatic antenna tuners can be placed at the antennas feed-point, but the disadvantage of them is that the ones available today will not handle high power.

A coax-fed dipole and a tuner should not be used to feed an antenna on its even harmonically related bands. The even harmonics are 2, 4, 6, etc, times the fundamental resonant frequency. If an 80-meter antenna being fed with coax through a tuner is used on 40 meters, it will put out a weak signal because the SWR will be around a hundred to one. Coax has a tremendous loss with SWR this high. Only a few Watts from a hundred-Watt transmitter will reach the antenna. However, you will be able to make contacts with those few Watts. If you want to use any antenna having high SWR, ladder-line has much less loss than coax. If you feed an 80-meter dipole on 40 meters using ladder-line and a tuner, it will only be slightly less efficient than a half-wave 40-meter coax-fed resonant dipole. However, the SWR will still be high between the tuner and the antenna, but this doesnt matter since ladder-line has an insignificant loss. Since the feed-point impedance will be high, the SWR will only be about 9:1 in the ladder-line because ladder-line is a high impedance feed-line.

Extremely short antennas may not work at all because of the above mentioned reasons. To reiterate, the extremely high capacitive reactance may make it impossible for its reactance to be tuned out and reactance prevents a transmitter from delivering power to the antenna. Even if you are able to tune out the capacitive reactance, tuning it out requires an inductor and most of the power will be lost in the inductor. Do not take the statement about the Conservation of Energy to mean you can put up any piece of wire and it will radiate your entire signal.

3. The Cause of Feed-Line Radiation

Contrary to popular myth, SWR in a feed-line will not cause it to radiate. The cause of feed-line radiation is unequal current in the two conductors of the feed-line. What are the causes of unbalanced current in a feed-line? They are an unbalanced feed-line feeding a balanced antenna; the feed-line being brought away from and parallel to one leg of the antenna; the antenna not being fed in its center; and one leg of the antenna being close to metal objects. In coax, unbalance causes RF to travel on the outside surface of the coax shield, and the shield radiates. When everything is balanced, coax normally has current flowing on its center conductor and on the inside of its shield. The shield prevents it from radiating.

Ladder-line will also radiate when it is fed from the output of a tuner not having a balun. Baluns are discussed in the next section. Since the output of a transceivers tuner is unbalanced and feeding ladder-line directly from your transceivers tuner, the currents in the ladder-line will not be balanced. When balanced, ladder-line has equal currents with a 180-degree phase difference, which produce waves that null each other out, and no radiation takes place. Hams mistakenly refuse to bring ladder-line into the shack because of a fear of feed-line radiation, but ladder-line does not radiate when balanced. The simple cure for feed-line radiation is to use a balun at the antenna feed-point for coax and a balun at the output of the tuner when using ladder-line.

4. Baluns

The word "Balun" is a contraction of " balanced to unbalanced." It is pronounced "bal un" like "bal" in "balanced and like "un" in "unbalanced". Many hams mistakenly pronounce an "M" at the end of the word making it "balum." A balun transforms the unbalanced transmitter output to a balance feed-line such as ladder-line. It is also used to connect an unbalanced feed-line such as coax to a balanced dipole. In the latter case, the balun is located at the antenna feed-point and is constructed so the balun takes the place of the center insulator.

There are two kinds of baluns: voltage baluns and current baluns. They both accomplish the same thing. The difference in baluns is in the way they are wound. A voltage balun produces equal voltage with opposite polarity at its output. As its name implies, a current balun provides equal currents with opposite polarity at its output.

Running the coax through ferrite beads can make a 1 to 1 current balun. In addition, you can build a 1 to 1choke current balun by winding 8 to 10 turns of coax around a two-liter soda bottle and placing the coiled coax at the antenna feed-point. Any balun is designed to "divorce" your antenna from the feed line. It is used to prevent common mode radiation of coax, which makes the coax to be part of your antenna. You want it to be able to deliver all your power to the radiator itself. A choke balun does this perfectly, without using any ferrite beads or toroids. In most cases common mode coax radiation does not occur when a balun is not used, but it is preferable to use one to be safe.

Other baluns provide a step-up or step-down impedance transformation. A 4-to-1 balun steps up the impedance four times. It will transform a 50-ohm impedance to 200 ohms. This type of balun transformer is used at the output of tuners to increase the tuning range of a tuner 4 times. If a tuner without a balun can match 500 ohms, a 4-to-1 balun will increase the range of impedances it can match to 2000 ohms. Many hams think the 4-to-1 balun is used to match 50 ohms to 450-ohm ladder-line but it is not. It would take a 9-to-1 balun to match 50 ohms to 450 ohms, and it is not important to match the impedance to ladder-line.

A balun should always be placed at the input end of ladder-line or open wire feeders to prevent feed-line radiation. When using ladder-line a step up balun is commonly used although a 1:1 balun will work.

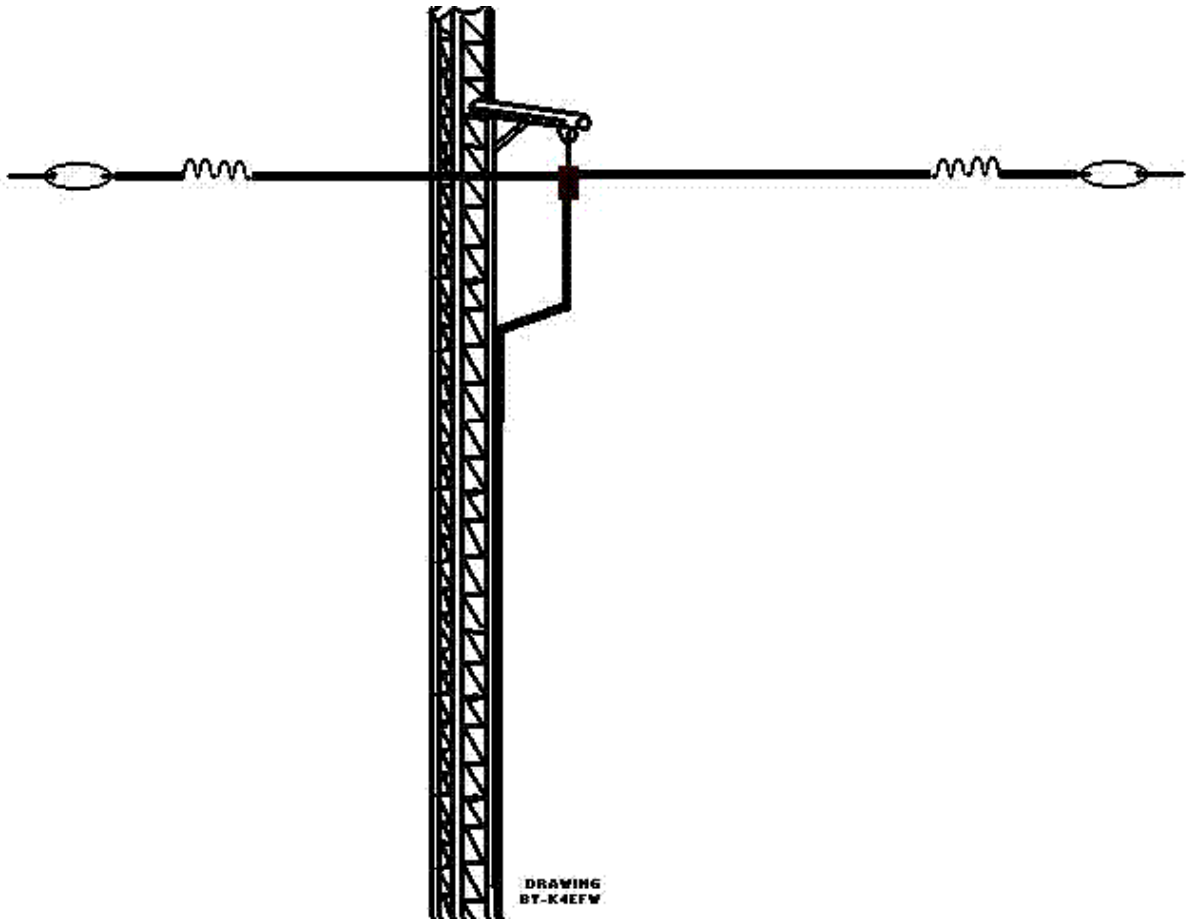
X. OTHER TYPES OF DIPOLES

1. A Shortened Dipole Using Loading Coils

If you are unable to put up a full-sized dipole on your property, putting loading coils into the dipole could shorten the antenna. See section IX, part 1. A short antenna has capacitive reactance and the capacitive reactance can be tuned out with a coil. The overall length of the shortened antenna will be determined by the amount of inductance in the coil. Pre-tuned antennas of this type are available from at least one manufacturer. The main problem with loaded antennas is they are very narrow banded. If the

loading coils are wound with small diameter wire, the coils may introduce unwanted loss into the antenna. Loading coils can also be found in shortened vertical antennas for high frequency (HF) mobile use.

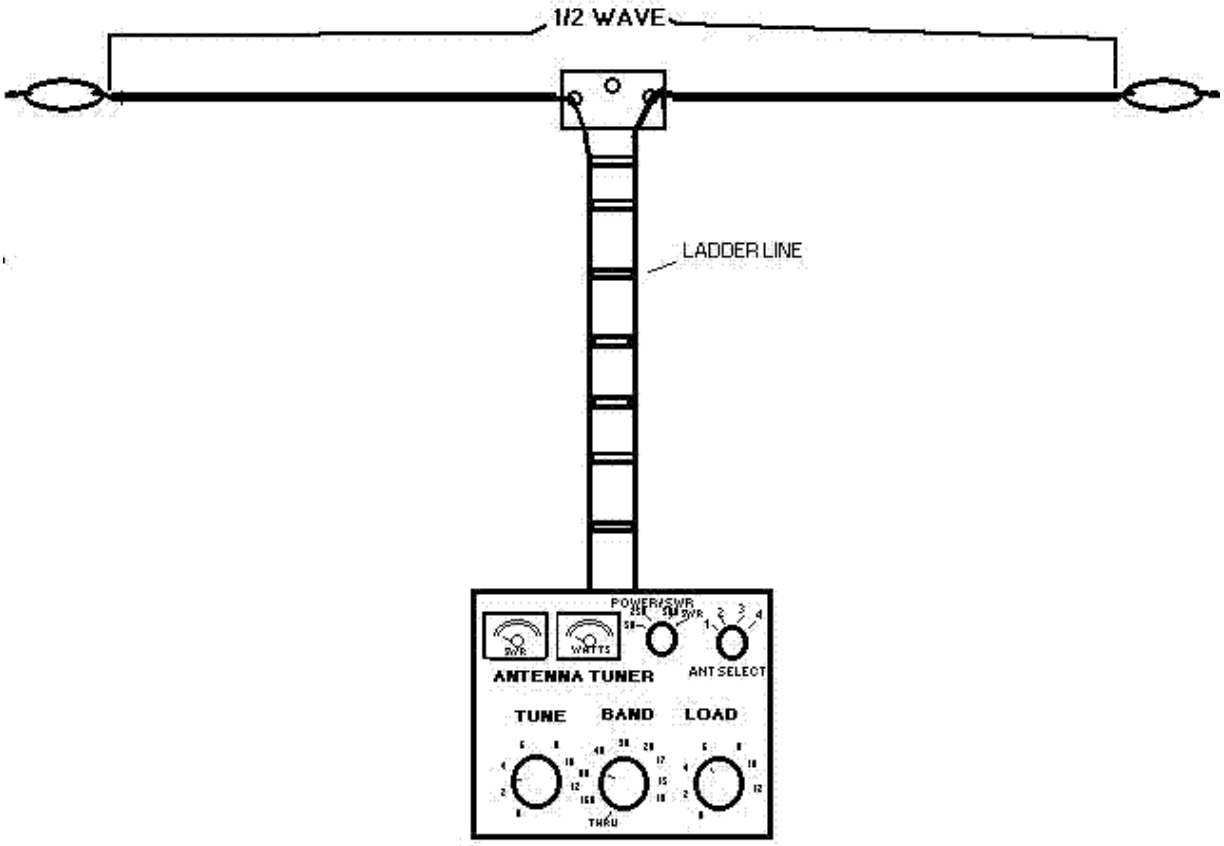
Figure 5. A Shortened Loaded Dipole



2. All Band Dipole

In the figure below, a dipole is cut to a half wave on the lowest band you want to operate. Feeding it with ladder-line and a tuner makes it possible for you to work all the other higher bands. The only losses in this antenna system are the loss in the tuner and the very small loss in the ladder-line. This system is more than 90% efficient. As mentioned above the balun in the tuner will be used, or if your tuner doesnt have a balun, an external balun can be connected between the tuner and ladder-line with a short run of coax. Four-to-one baluns are the most commonly used ones for this arrangement.

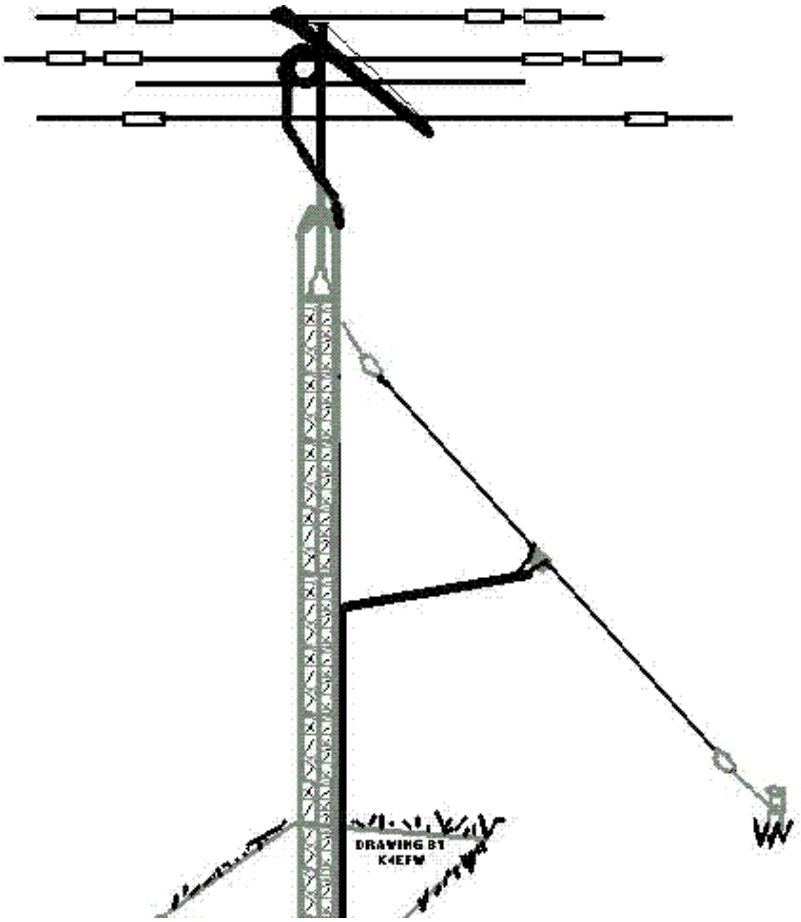
Figure 6. All Band Dipole



3. The Sloping Dipole

A lower angle of radiation can be achieved by tying one end of a half-wave dipole to a high support and the other end near the ground. It is fed with or without a balun with 50-ohm coax. The sloping dipole will show some directivity and have low angle gain in the direction of the slope. More directivity can be gained if the dipole is strung from a tower, and the tower is acting as a passive reflector. The sloping dipole is mostly a vertically polarized radiator and it works well for DX. Since the sloping dipole is fed in its center, it does not need to be grounded to the earth as a quarter-wave vertical does. Make sure the bottom end of a sloping dipole is at least 10 feet above ground because like all dipoles there is high RF voltage on its ends.

Figure 7. Half-Wave Resonant Sloping Dipole



In the picture above, the field of maximum radiation is in the direction of the slope or toward the right side of the picture. The formula for the length of a sloping dipole is the same for any half-wave resonant dipole.

4. The Folded Dipole

The B&W Company makes a folded dipole that claims to have a good match on all bands and it does. However, on the low bands much of the power is burned up in the resistor that connects the two ends together. The power going toward the ends encounter the resistor and is consumed as heat. All that power is lost and does not radiate, and no power is reflected back to the feed point making the antenna have low SWR. On the higher bands, a large part of the power radiates before it reaches the resistor and the antenna is moderately efficient on those bands. On 80 meters the 90 foot-long dipole model will produce a signal at least 10 dB lower than that from a resonant dipole.

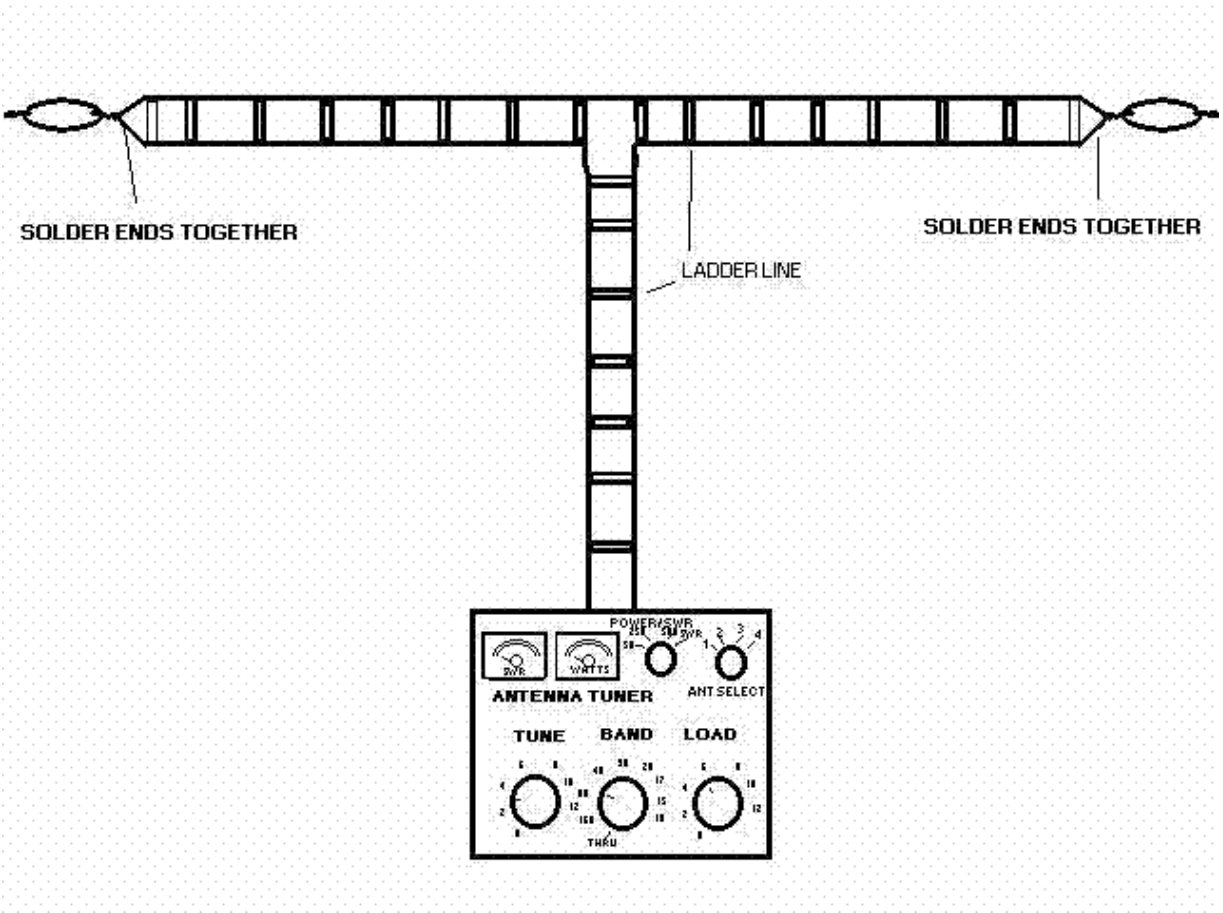
If you remember the single channel TV antennas used years ago, the driven element was a folded dipole. Folded dipoles are very broad-banded. That is the reason they were used for TV antennas since a TV channel is 4 MHz wide.

When constructing a folded dipole, the formula for calculating the length of it is the same as for any dipole. The folded dipole consists of two parallel conductors with the ends tied together. The conductors can be spaced from less than an inch to more than two inches apart when made from TV ribbon or ladder-line. At the ends, strip the insulation back several inches, Twist the bare wires together, solder them, and run them through insulators. The feed-point is in the center of only one of the two parallel conductors.

The feed-point impedance of a folded dipole at resonance is close to 300 ohms resistive and can be fed directly with 300-ohm TV twin-lead or a tuner with its balun. This antenna was very popular years ago when coax was expensive and 300-ohm TV twin-lead was relatively cheap. A length of 450-ohm can be substituted for the twin-lead. An alternate feed method is placing a 6:1 balun at the feed-point and then feeding it with 50-ohm coax. The folded dipole will not radiate its second harmonic, so it is not good for a multi-band tuner-fed antenna.

Another folded dipole type is the three wire folded dipole. We have seen this dipole only in books and do not know anyone who uses one. The feed-point impedance is 600 ohms resistive and is fed with home-built 600 ohm open wire feeders.

Figure 8. Folded Dipole



5. The Double Bazooka Dipole

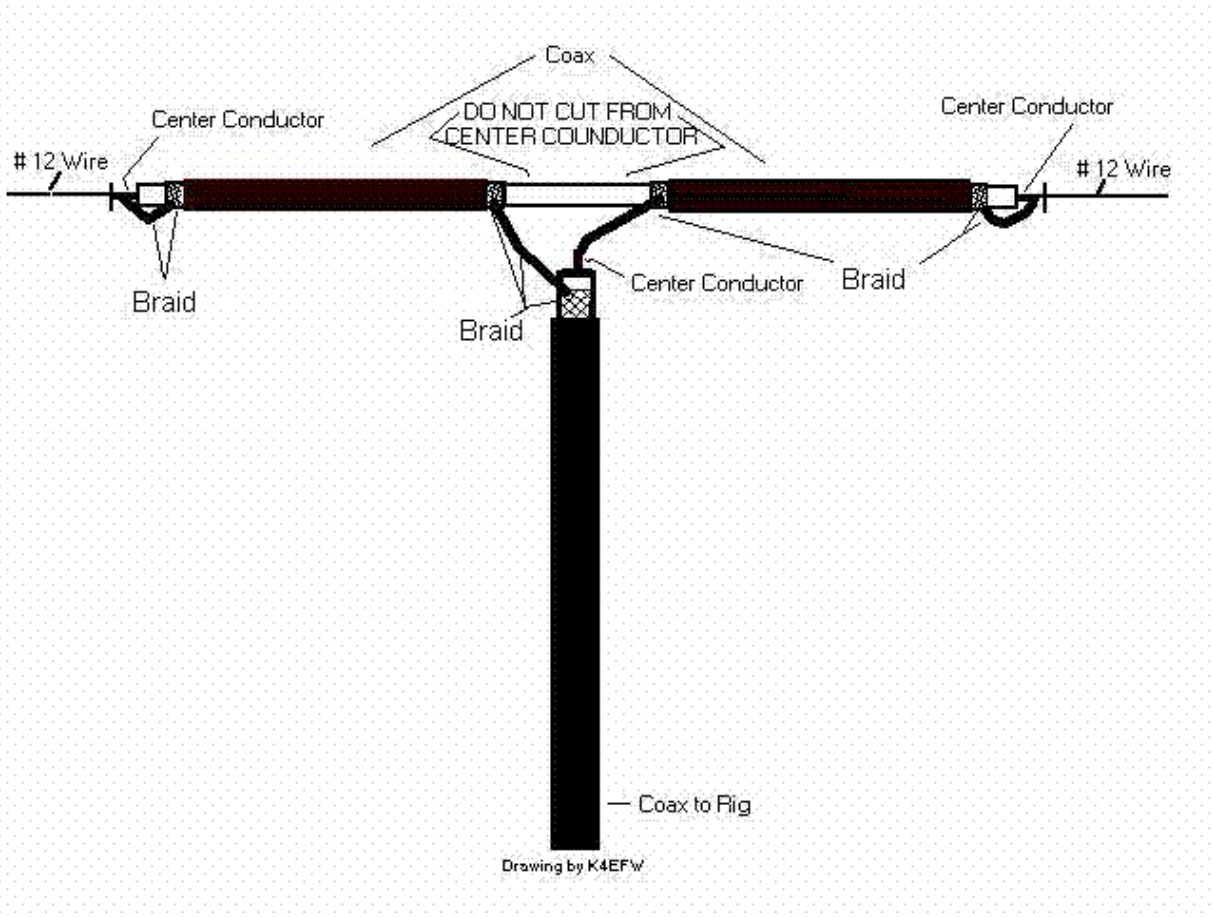
The double bazooka is claimed by its users to be broad-banded, a quality especially interesting for those hams operating on 75/80 meters. Tests done at the A.R.R.L. have shown the double bazooka is only slightly more broad-banded than a regular dipole, probably due to the use of a large conductor (coax) for the center part of the antenna. The double bazooka will not transmit its second harmonic, and its users say it does not need a balun. Other users say it is quieter than a regular dipole.

The center of the antenna is made from RG-58 coax. To find the length of coax needed, divide 325 by the frequency in MHz. The coax forms the center part of the double bazooka and a piece of number 12 wire on each end completes the antenna. The length of each of the end wires is found by dividing 67.5 by the

frequency in MHz. To increase the bandwidth some builders use shorted ladder-line in place of the number 12 wire, which makes the end pieces to be electrically larger.

The feed-point of the double bazooka is unique. At the center of the coax dipole, remove about 3 inches of the plastic covering, exposing the shield. Cut the shield in the center and separate it into two parts. Do not cut the dielectric or the center conductor. Leave the center conductor with its insulation exposed. On the feed-line strip off about 3 inches of outer insulation, separate the shield from the center conductor, and strip about 1 inches of the insulation from the center conductor. To attach the feed-line, solder the two exposed feed-line conductors to the two pieces of the separated exposed shield of the dipole center. It goes without saying: seal the feed-point to prevent water from getting in. At each of the two ends of the coax forming the center of the antenna, the coax is stripped back and the center conductor and shield are shorted together and soldered. The end wires are soldered to the shorted coax ends, run to insulators at the end of the antenna, and the soldered joints are sealed against the weather.

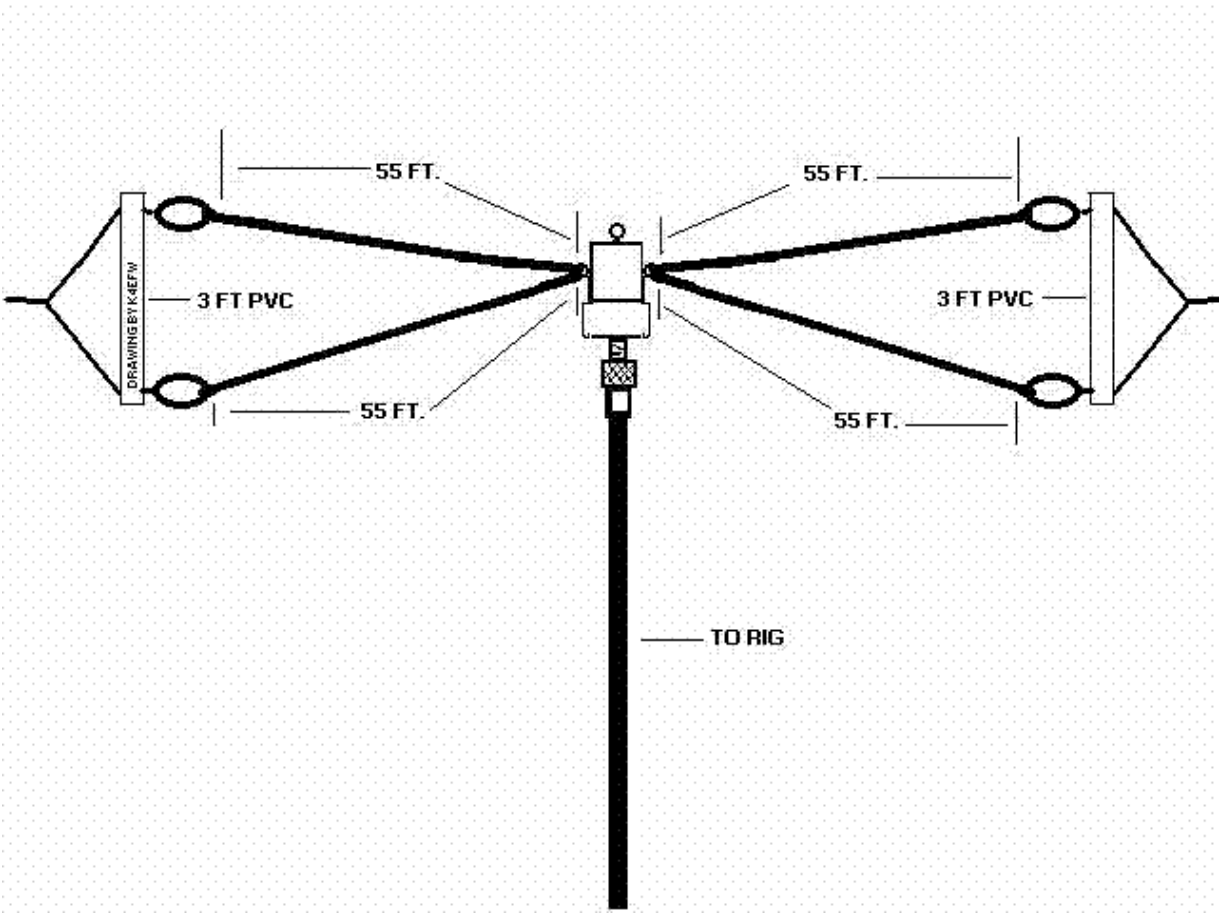
Figure 9. Double Bazooka Dipole



6. Broad-Banded Coax-Fed Fan Dipole

A broad-banded dipole for 75/80 meters can be constructed by attaching two equal length dipoles to the center feed-point and spreading the ends about 3 feet apart using PVC water pipe to separate them. The completed dipole looks like a bow tie. This makes the antenna to appear electrically to have that of a large diameter conductor. Because of this, the overall length will need to be shorter than a single wire alone. When we used the antenna, we found a length of 110 feet would cover most of the 75/80-meter band without a tuner. It is fed with 50-ohm coax. The use of a balun is optional. The antennas for most of the higher bands have enough bandwidth so they do not need broad banding.

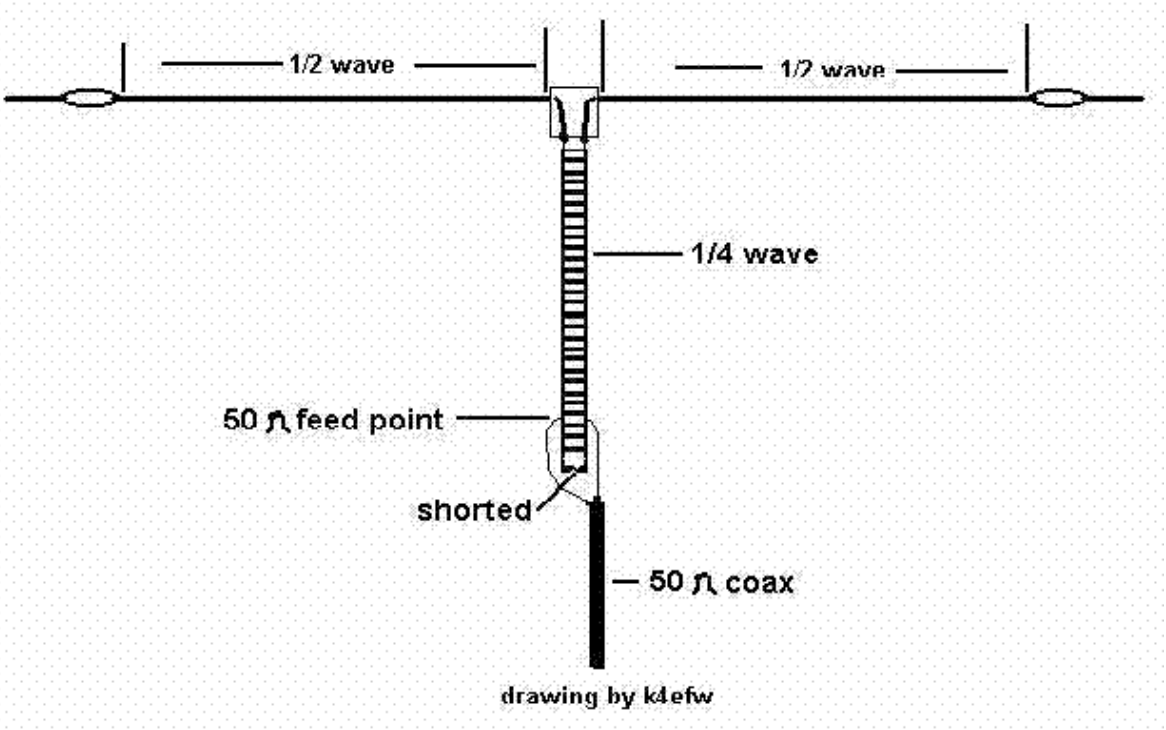
Figure 10. Broad-Banded Fan Dipole for 80 Meters



7. Two-Element Collinear Dipole

The two-element collinear dipole is an antenna that is a full-wavelength antenna having a two-dBd gain. It can be fed with ladder-line and a tuner and used as a multiband antenna, or it can be fed with a quarter-wave-matching stub with 50-ohm coax cable to make it a single band array. In the stub matching system, a quarter wavelength of ladder-line is connected across the center insulator, and the opposite end of the ladder-line is shorted. A shorted quarter-wave piece of feed-line acts like an open circuit. Going from the shorted end of the ladder-line toward the dipole, there will be a point where a piece of 50-ohm cable will find a perfect match. The 50-ohm feed-point will have to be found empirically (trial and error).

Figure 11. Two Element Collinear Dipole



8. Four-Element Collinear Dipole

The four-element collinear dipole array consists of four half-wave segments connected end-to-end with an insulator between each two adjoining segments. The feed-point is at the center of the array. The antenna is fed with ladder-line through a tuner. A quarter wave shorted ladder-line stub hangs down vertically from the insulators between the inside and the outside half-wave segments. This stub provides a 180-degree phase shift so that all half-wave segments are fed in phase. This antenna has a 6-dBd gain and it radiates bi-directionally at an angle perpendicular or broadside to the plane of the wires.

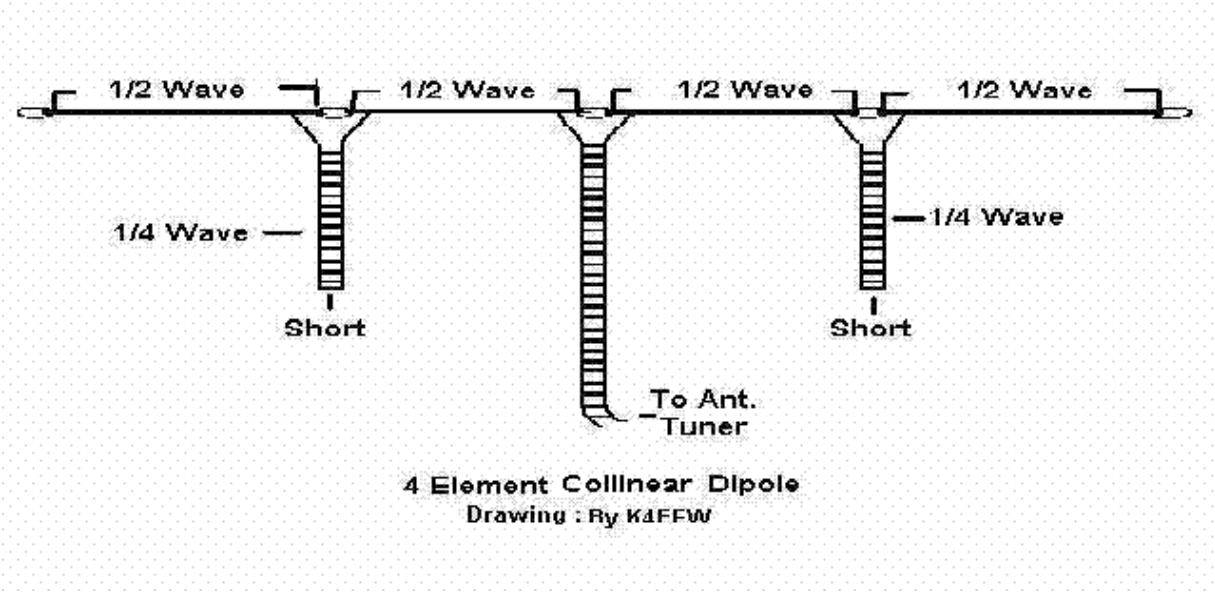
This antenna is too long for most hams to use on 80 and 40 meters, and the stubs hanging vertically will be too close to the ground. For 20 meters, the four-element collinear array will be 97 feet long and the stubs will be 18 feet. To find the length of each half-wave segment, divide 468 by the frequency in MHz, and for the quarter-wave stubs, divide 246 by the frequency in MHz.

MFJ has begun marketing the four-element collinear monoband array. They have them for 20, 17, and 15 meters. This antenna is so easy to build that you can do it yourself. All you need is 5 insulators, antenna wire, and some ladder-line.

It will have no gain if you use it on bands for which it is not designed because the stubs are used as phasing lines. It is definitely not a multiband antenna.

It is possible to add more half-wave segments to the ends of this array to make it have 6, 8, 10, etc half wave segments. Adding more segments will add more gain and make the lobes narrower.

Figure 12. Four-Element Collinear Dipole



9. Coax-Fed Dipoles Operated on Odd Harmonic Frequencies

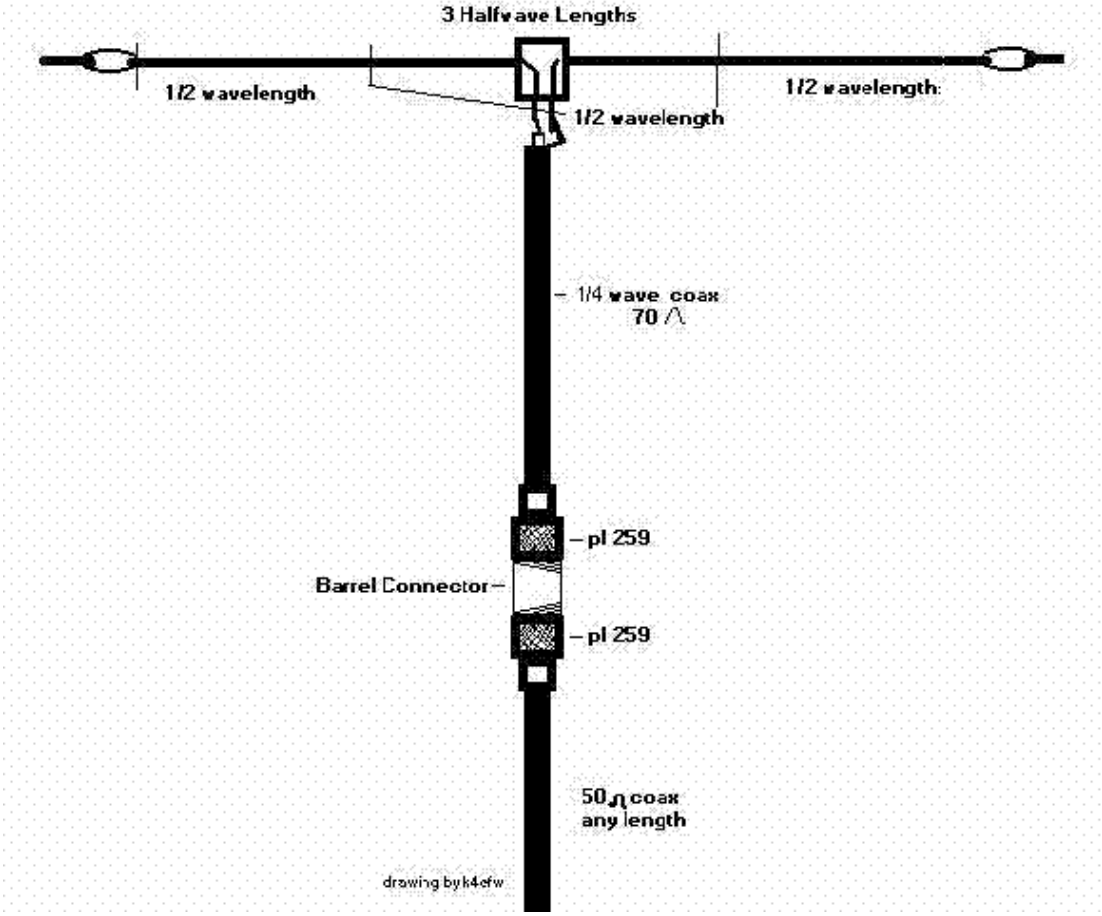
Antennas fed with 50-ohm coax can be used on other bands for which they are not cut. An 80-meter dipole will have a relatively low SWR and will be resonant at a single frequency on 10 meters and not

much power will be lost in the coax even if operated off resonance. A 40-meter dipole will work the same way on 15 meters. Using coax, a dipole will work on its fundamental frequency and on odd-harmonic frequencies and it is not necessary to use ladder-line. The fundamental frequency is the frequency for which the antenna is a half-wavelength long, and the odd harmonics are 3 times, 5 times, 7 times, etc. the fundamental resonant frequency. A frequency of 21 MHz is 3 times or the third harmonic of 7 MHz, and 28 MHz is the seventh harmonic of 4 MHz.

Antennas operated on their odd harmonics will be resonant a little higher in frequency than exact multiples of their fundamental frequencies. Since the odd harmonic antennas input impedance is higher than it is on its fundamental frequency, many amateurs use a series quarter-wave matching section of 70-ohm coax to give it a better match. The 80 meter inverted-V dipole in use here has a 2:1 SWR on 10 meters indicating it has an impedance of around 100 ohms. However, modeling the antenna for 10 meters shows the resonance to be below 28 MHz, probably because the antennas fundamental resonant frequency is 3920 instead of 4000 kHz. A quarter wave 70-ohm matching section should bring the SWR down to a much lower level.

As said earlier, if you try to use coax with a dipole on its even harmonic frequencies, the feed-point impedance will be very high, the SWR will be extremely high, and the coax will absorb most of the power. In addition, when operating a coax-fed antenna on its even harmonics, the tuner may not be able to provide a match. Operating any antenna on any of its harmonic frequencies, odd or even, will work better if it is fed with ladder-line and a tuner.

Figure 13. Three Half-wave Dipole

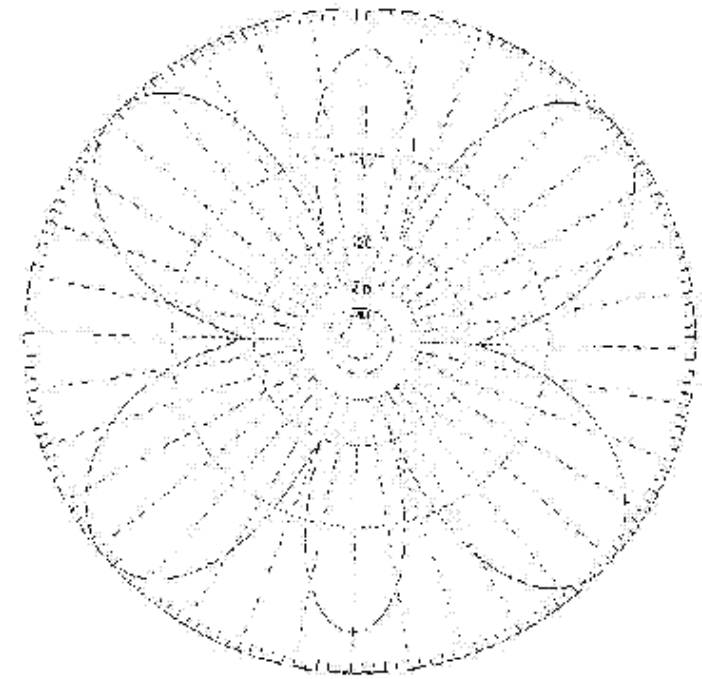


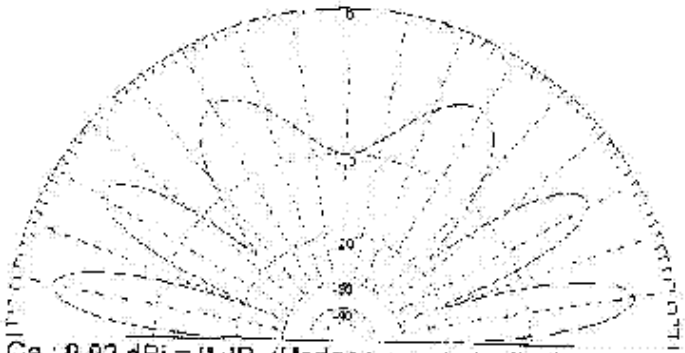
This antenna is matched by a quarter-wave 70-ohm series matching section. Three half waves will resonate higher than you would expect because the center half wave doesnt have to contend with end effects. To calculate the length of a three half-wave dipole, divide 1380.6 by the frequency in MHz. Five half waves is found by dividing 2316.6 by the frequency.

To use a 3 half-wave antenna on 15 meters, the 70-ohm matching section needs to be 7 feet 7 inches and the antenna needs to be 64 feet long for a good match. It will be just a little long on 40 meters. When using a 40-meter dipole with a 15-meter quarter-wave matching section, it will still have acceptable SWR on 40 meters.

Figure 14. Radiation Pattern of a 15- Meter Three Half-Wave Dipole at 65 Feet

MMANA-GAL v. 1.0.0.65





Ga : 8.03 dBi = 0 dB (Horizontal polarization)
F/B: -2.24 dB; Rear: Azim. 120 dg, Elev. 60 dg
Freq: 21.300 MHz
Z: 133.724 - j28.622 Ohm
SWR: 2.3 (50.0 Ohm), 5.8 (600 Ohm)
Elev: 8.8 dg (Real GND, 20.00 m height)

The pattern shows 6 lobes, 4 major lobes and 2 minor lobes. The vertical radiation pattern shows low angle radiation.

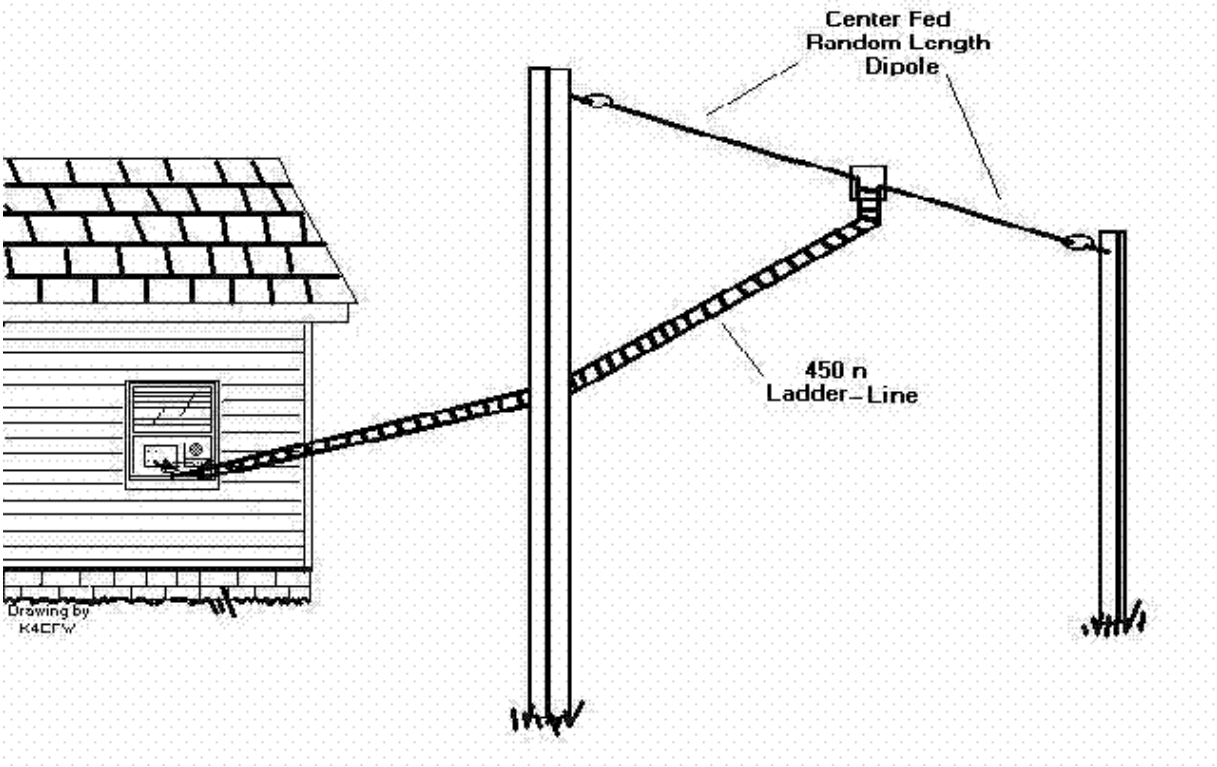
10. All Band Random Length Dipole

A random length of wire cut into two pieces can be used as a dipole, and it will radiate efficiently. It has to be at least a half-wave length on the lowest band you want to work. It looks the same as the all-band dipole and is the same, except it is not resonant on any band. The random length dipole is being described here to emphasize that the radiating part of an antenna doesnt have to be resonant. Because it

will have a feed-point impedance that is unusual, it must be fed with ladder-line a tuner, and a balun. Since you are using a tuner, it can be used on multiple bands. If you make it very long, it can have gain over a dipole. For example, if it is four wavelengths long, it will have 3-dBd gain. As you move to higher bands, the electrical wavelength of the antenna increases, and each higher band will have more gain.

A half-wave antenna radiates perpendicularly to the plane of the wire. As you move to higher bands, this antenna begins to show some gain, and instead of two lobes of radiation, the two lobes split into four lobes and the pattern resembles a 4-leaf clover. As you make the antenna longer, the four lobes move nearer the to the ends, the gain increases, and there are minor lobes of radiation between the major lobes. These minor lobes make it possible to work in all directions. The longer the wire, the closer the antennas major lobes radiate bi-directionally toward its ends

Figure 15. All Band Center-Fed Random Length Dipole



The problem with using a random length of wire for this antenna is you may find that because of limitations of your tuner, you may not be able to tune a particular length of antenna on some bands. Certain lengths will tune all bands and one of those lengths is 135 feet. That particular length will be nearly resonant on all bands of 80-10 meters. Resonance only makes it easier to tune, but it has no effect on efficiency. A length of 260 feet will tune from 160-10 meters. Lengths of 260 and 135 feet have been used here successfully. Some hams use random lengths of wire without problems. Then some hams have had problems with other random lengths. The ones having the problems solved the tuner problems by changing the length of the dipole wire. If you plan to put up this antenna using a random length of wire, you will need to experiment with various lengths until you find a combination that works.

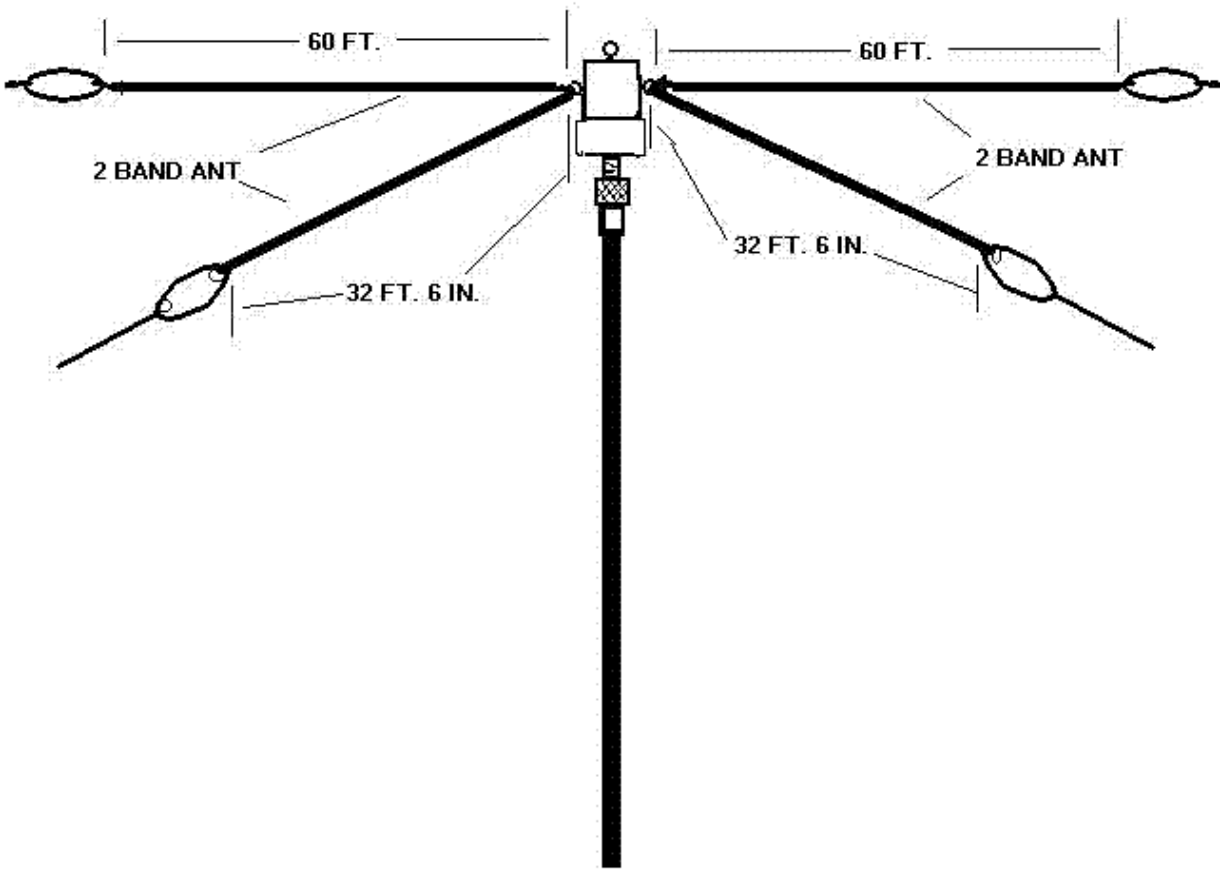
Tests were performed here using two towers of equal height and spaced 100 feet apart. On one tower, was an 80-meter inverted-V 120 feet long fed directly with coax, and running parallel to it on the other tower was a 135-foot long inverted-V fed with ladder-line and a tuner. At the resonant point of the coax-fed dipole and having tuned the ladder-line fed antenna, it was possible to switch antennas instantly and

many hams were asked to look at their "S-meters" while the antennas were switched. All hams that participated in the test said the signals from both antennas were equal. The signals were measured on analog S-meters, not on segmented LCD meters found on most of todays transceivers.

11. A Two-Band Fan Dipole

A two-band dipole can be constructed by connecting together the feed point two dipoles for even harmonically related bands. It is fed with 50-ohm coax with or without a balun. The best example of this is 80 and 40-meter dipoles connected together. Both dipoles are cut for half-wave resonance on each of the two bands. They are fed together and the ends of the wires are spread apart. If the ends are close together, there will be interaction between the dipoles. In such an antenna system, both dipoles must be carefully pruned for lowest SWR one band at a time. The lower band will be tuned first since the shorter dipole will not interact with the longer one. Each dipole has a low antenna resistance on the band for which it is resonant. RF energy follows the path of least resistance, and it automatically selects which dipole will receive power. The remaining antenna will have a high impedance. High impedance will block RF. Such an antenna will have a narrower bandwidth than a single band dipole, but close to the resonant frequency of each dipole, a tuner will not be needed. To connect many dipoles for multiple bands is possible, but it is not recommended because multiple wires are prone to interact and it will be impossible to achieve a low SWR on some bands. However, on the two band model, the 40-meter dipole will resonate close to 15 meters, the 80-meter dipole will resonate close to 10 meters, and working four bands with this set-up is possible. Some hams are using this antenna successfully with a tuner on all bands, although the signal on 20 meters suffers somewhat because of high SWR.

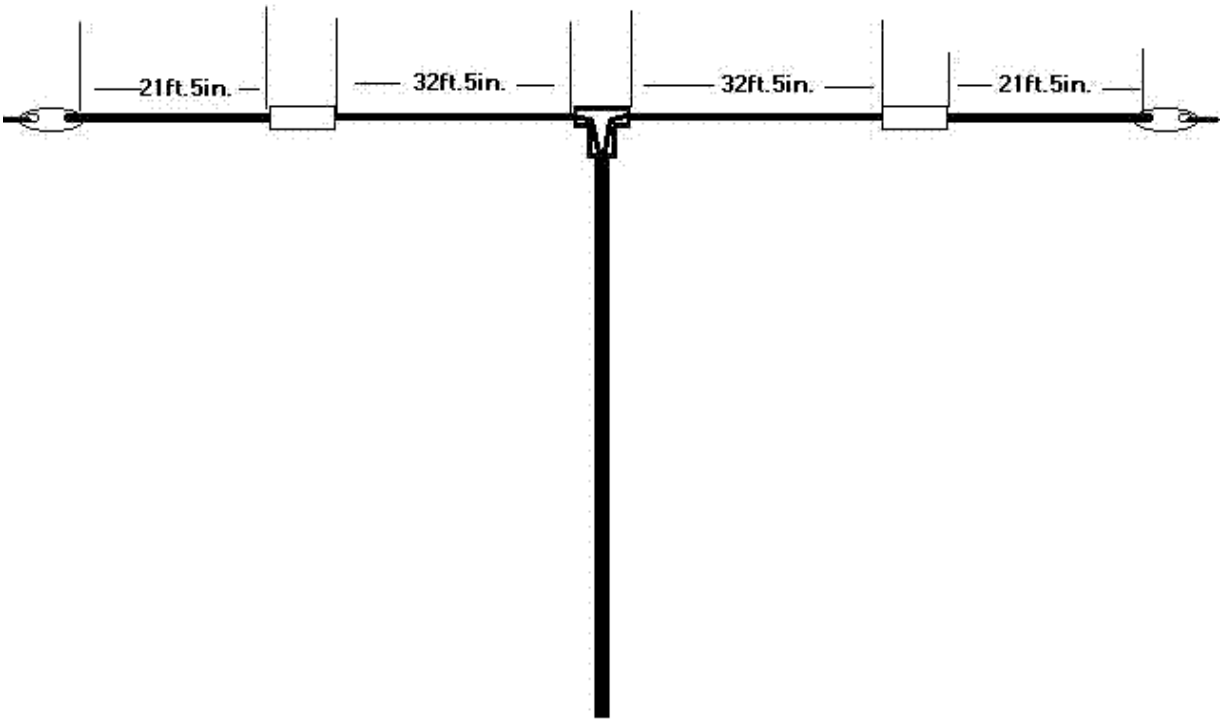
Figure 16. Two-Band Fan Dipole for 40 and 75 Meters



12. Trapped Dipole for 75 and 40 Meters

A trap is constructed from a capacitor and an inductor connected in parallel. It acts as an open switch on the frequency for which it is resonant. A trap is placed on each side of the dipole. For a 75 and 40 meter trapped dipole, the traps must be resonant on 40 meters, and each trap should be placed a quarter wave from the center insulator. The center section between the traps is electrically isolated from the ends of the dipole by the traps on 40 meters, and the center section of the antenna becomes a full-sized half wave resonant dipole for that band. This antenna is fed with 50-ohm coax and an optional balun. Wires connected to the outside of the traps are run to the end insulators and are tuned so the entire antenna resonates on 75 meters. The 75 and 40 meter trapped dipole will be shorter than a 75-meter dipole because the inductor in the 40-meter trap acts as a loading coil on 75 meters. In addition, the ends of the antenna can be tuned to operate on the 80-meter CW band instead of the 75-meter voice band. Several sets of traps can be inserted at the correct points in the dipole to make a multi-band dipole. Multi-band trapped dipoles are being sold, but in many cases they will require the use of a tuner. If a good match is found at a frequency on some bands, the bandwidth without a tuner will be very narrow.

Figure 17. Trapped 75 and 40-Meter Dipole

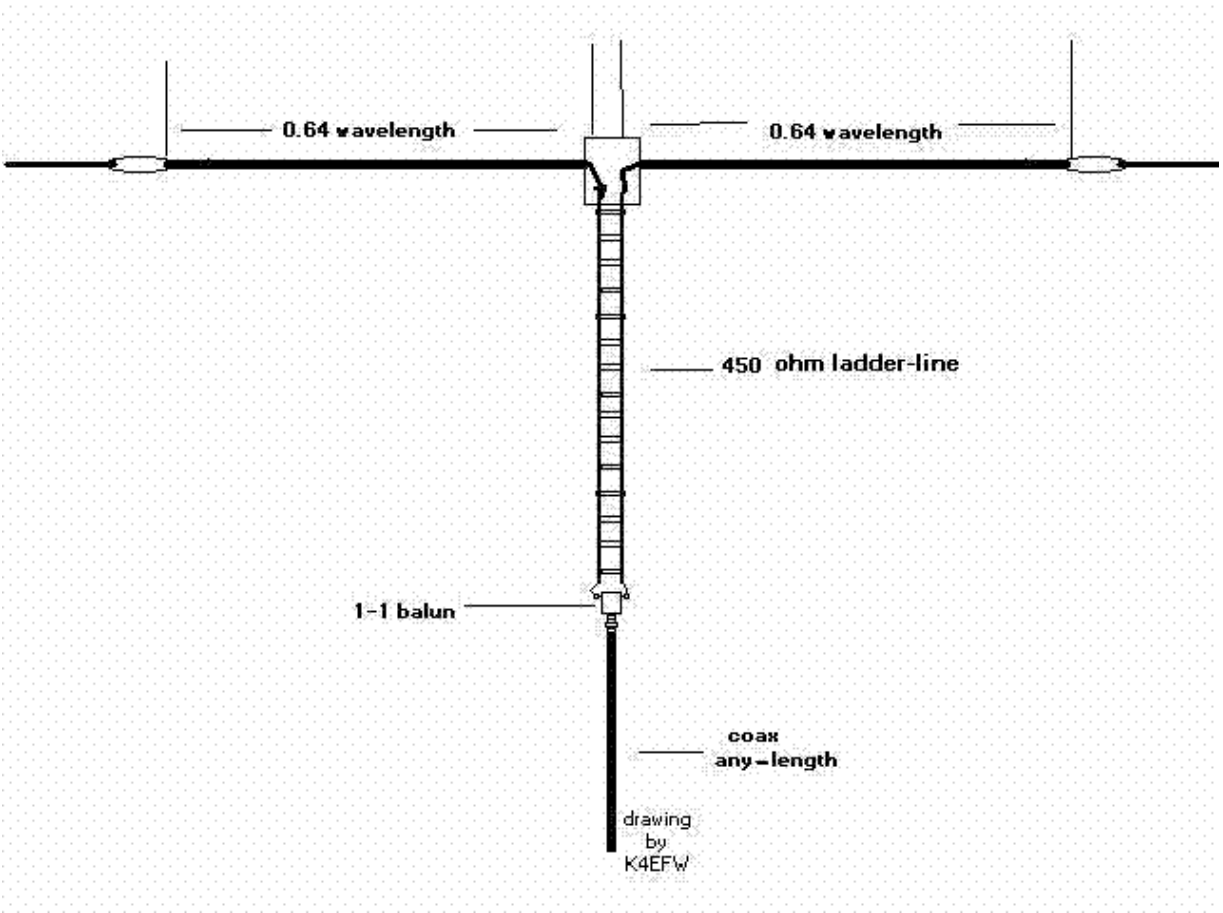


The antenna is only 108 feet long instead of 120 feet because of the loading effect of the traps on 75 meters. These dimensions are for antennas using the traps made by W2AU. If you use other brands of traps, the length of the end wires will have to be adjusted. What you do in that case is make the wire long, measure its resonant frequency on 75 meters, and prune the ends to resonance at your favorite frequency.

13. The Extended Double Zepp Dipole

An extended double zepp is a long dipole with 3-dBd gain. It is the longest dipole antenna, which will radiate at right angles to the plane of the antenna. To find the overall length of an extended double zepp, divide 1197 by the frequency in MHz. Each leg of the antenna is 0.64 wavelength long and the total length is 1.28 wavelengths. An extended double zepp for 75-meters at 3.8 MHz is 315 feet. Not many amateurs have space for that antenna. The extended double zepp is mostly fed with ladder-line. Another method of matching an extended double zepp is to use tuned lengths of 450-ohm ladder-line as a series matching transformer connected between the 50-ohm coax and the dipole. The length of the matching section of 450-ohm ladder-line can be found by dividing 135 by the frequency in MHz.

Figure 18. Extended Double Zepp Dipole



14. The G5RV Dipole

An interesting antenna you can buy that will work somewhat on all high-frequency bands is the so-called G5RV antenna. It is named after the call letters of Louis Varney (SK) who designed it. It is a 102-foot long or three half-wavelength dipole antenna on 20 meters (14.150 MHz), and can be used with a tuner on other bands as well. In his original design, Varney calculated the length to be 102.57 feet, but chose to make it an even 102 feet since a tuner was going to be used with it anyway. It was originally fed through a 34-foot 500-ohm homebrew open wire matching section from a 70-ohm coax or parallel conductor feed-line. The 34-foot open wire line is a half wavelength on 20 meters and at the end of a half-wave feed-line, you will see the antennas impedance repeated regardless of the feed-line impedance. The ladder-line helps partly to match the antenna on the other bands.

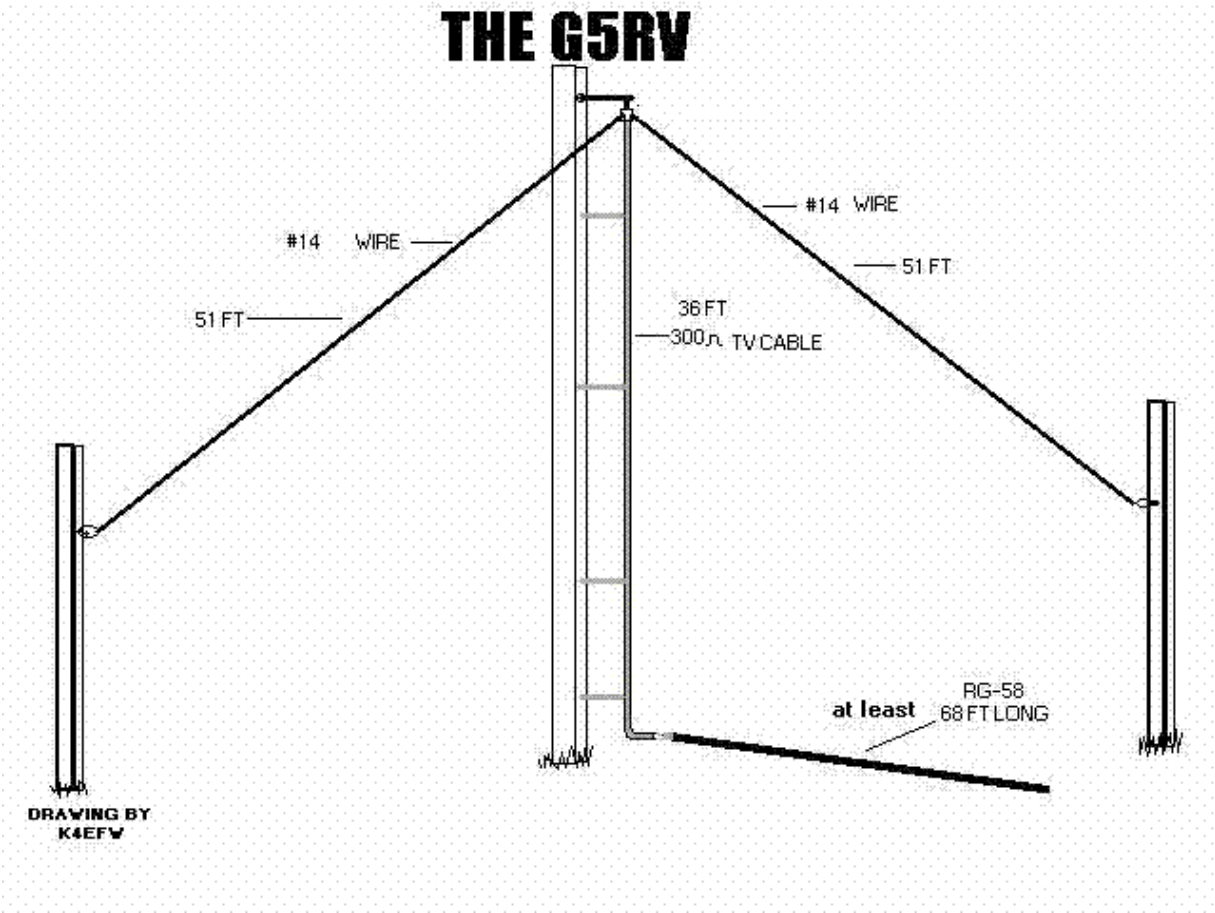
The G5RV antenna is around 20 feet short of being a half-wave on 80 meters, and on bands on 20 meters and up, it has theoretical gain. We believe that gain is negated by losses in the coax of the feed system, except for 20 meters. At the frequency of the best match, commercially made models of the G5RV are

said to have a 1.8:1 SWR on 80 meters. Where the coax joins the open wire, Varney recommended using a choke made of 8 to 10 turns of coax. He advised against using a balun, because, as he says SWR of 2:1 or higher may cause the balun to heat and possibly burn out. The SWR will be moderately high or high on bands other than 20 meters. Varney recommends using the lowest loss coax available and as short a run as practical because of feed-line losses caused by high SWR. This recommendation is very important today, as it was when Varney designed it. Some G5RV antennas put out decent signals and some others have relatively weak signals. Without further investigating, the only way to explain this is that some are using lossy coax and baluns while others are not, and the height above ground may play a part in how well it works.

The G5RV antennas being made today use small diameter 50-ohm coax, 450-ohm ladder-line, and a balun between the ladder-line and the coax, contrary to Varneys suggestions. There are several variations of the G5RV antenna being sold today because many believe they can improve the original design. If you use a G5RV antenna, a tuner will be required.

The G5RV shown below is close to the original version of the antenna. This one pictured below is from an old article that K4EFW found somewhere. It is like the one he used. As you can see, it uses 300-ohm TV ribbon. The length of the parallel TV ribbon is 36 feet, but modern designs of this antenna use 34 feet of 450-ohm ladder-line. All these variations work equally well when they are used with a tuner. It is shown in the inverted-V configuration but it could be put up in the flattop configuration as is, with no modification.

Figure 19. G5RV Dipole

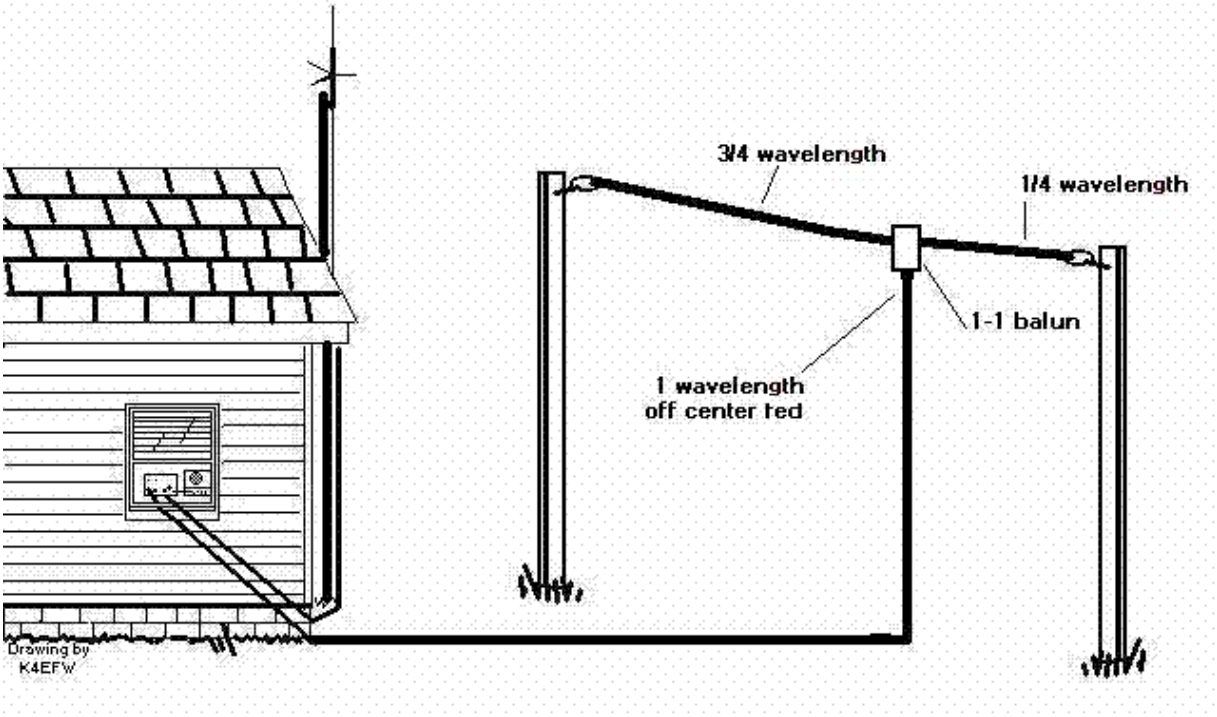


Jeff, AI8H, in Oxford, Georgia, had a pair of G5RV dipoles oriented in different directions. Recently he put up a 75-meter half-wave inverted-V. Being able to switch antennas, he ran A-B tests on 3902 kHz and the inverted-V was 10 dB stronger than the first G5RV and 15 dB stronger than the other one. Now if we are saying the stronger signal is 40 dB over S-9 and the weaker signal is 25-30 dB over S-9, no one will notice the difference. Only under marginal band conditions will the difference be important. In addition, the G5RV antenna will work better on the other bands.

15. Off-Center Fed Dipoles

A long dipole consisting of multiples of equal half-wave segments is normally fed in the center using ladder-line. Dipoles do not necessarily have to be fed in the center. They can be fed in the center of any one of these half-wave segments, even fed off-center. A fair match will occur if coax is used.

Figure 20. One wavelength Off-Center Fed Dipole



The dipole shown above is a one-wavelength dipole. It is nothing but two half waves end to end. It is being fed in the center of one half-wave segment or a quarter wave from one end. It is possible to make it any number of half waves, and if it is fed a quarter wave from one end, it will have a fair match. The way it is shown above is an example of how to feed an antenna with even multiples of a half wave using coax. A 2:1 or 4:1 balun will improve the match on longer versions.

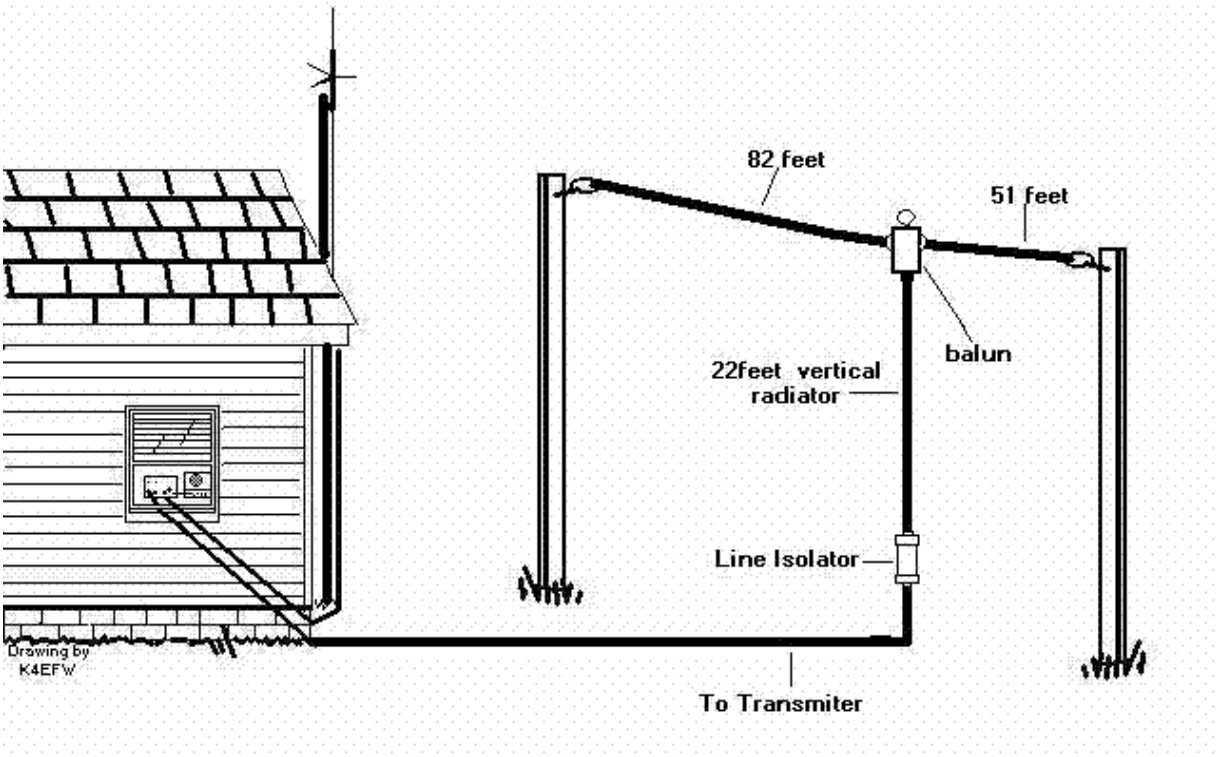
The windom antenna is another example of an off-center fed antenna. The original windom was fed off center with a single wire. The other side of the transmitter was connected to ground. The feed-point impedance at the transmitter was reported to be 500 ohms on all bands. The antenna was designed by William L. Everett and J.F Byrne at Ohio State University. W8GZ, whose last name was Windom, described the antenna in the September 1929 issue of QST.

A lot of research concerning the modern variations of the Windom antennas has been done, including the ones described by Fritzel, K4ABT, W4RNL, The Carolina Windom, and ON4BAA. The main differences in these variations are the slight differences in the position of the feed-point and the impedance of the baluns used for matching. The Windoms are sensitive to the height over ground,

meaning the height above ground affects the SWR. The offset position of the feed-point will also determine the feed-point impedance. The one sold by K4ABT is a variation of the Fritzel antenna, and the one sold by Radio Works, The Carolina Widom , claims it has a vertical radiator.

There are two variations of Windoms, both claiming they have vertical radiators, The Carolina Windom, and the one previously marketed by W4COX have two pieces of transmission line in series. The upper piece is connected to the dipole, and the lower piece is connected to the transmitter. The feed-point of the dipole is placed off center. In The Carolina Windom being marketed today, the upper transmission line is coax. The one made by W4COX had the upper piece made from ladder-line, but in either case, the principle is the same. The two pieces are connected together through a line isolator, a type of balun. The line isolator keeps the lower piece of transmission line from radiating. Because the antenna is fed off-center, the marketers of The Carolina Windom claims it causes an unbalance of current in the upper piece of transmission line. This is doubtful because there is a balun at the feed-point, which should prevent the feed-line attached there from radiating. The main difference between The Carolina Windom and the one sold by W4COX is that a 4:1 transformer is between the coax and the ladder-line, and a 1:1 line isolator is between the upper and lower coax cables. Both variations of this antenna show low SWR on several bands, but a tuner is used to match it.

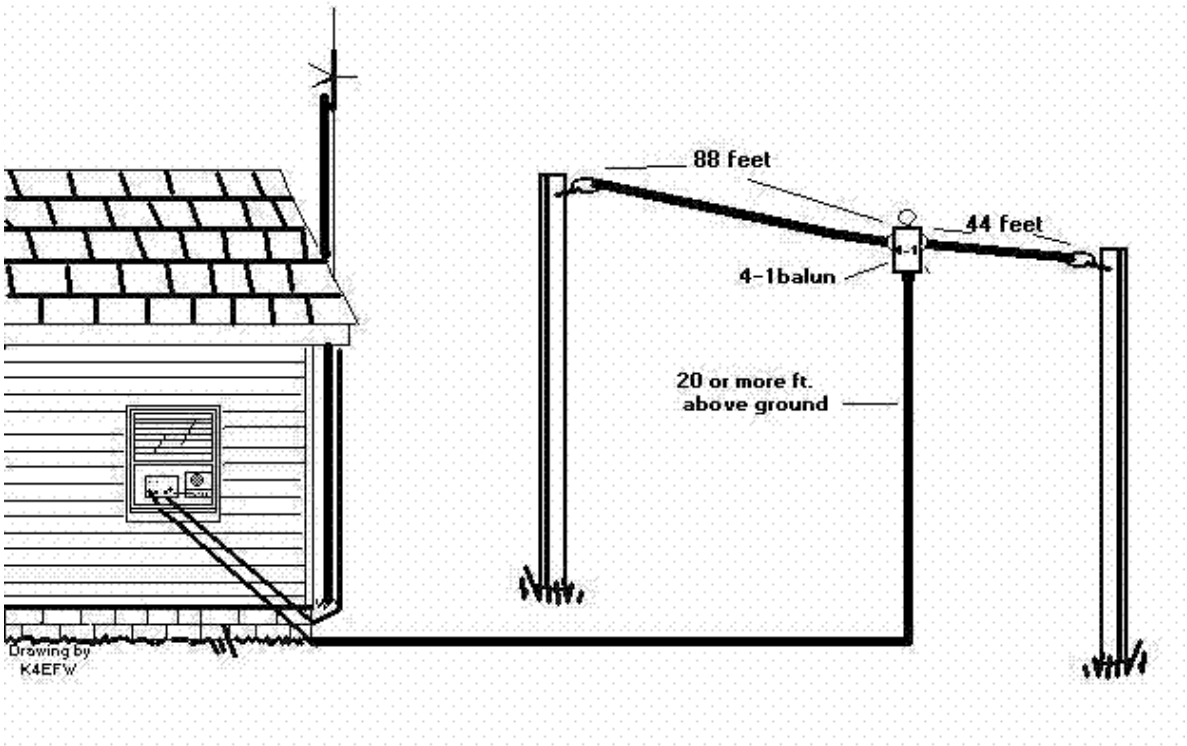
Figure 21. Carolina Windom



Another unique variation of the Windom dipole is the Fritzel antenna, named after its inventor and manufacturer, Dr. Fritz Spillenger (SK), a German ham, call sign DJ2KY. Alpha Delta is now selling an almost exact duplicate of the original Fritzel antenna. Alpha Delta calls it an OCF antenna and it is made by Buckmaster Antennas. There are two models of the Alpha Delta antenna: one for low power and one for high power, the power rating of the balun being the limiting factor. The Fritzels short side is 0.18 wavelength long and its long side is 0.32 wavelength long. It is fed with coax and a 6:1 balun. Theoretically, the feed point impedance is 300 ohms, and the balun provides a 50 to 300 ohm impedance transformation. Modeling the antenna on its lowest resonant frequency at 35 feet, it shows about 120 ohms impedance. The original Fritzel antenna being used by K4LMS reportedly will work all bands with a tuner, but it will work 40, 20, 17, 12, and 10 meters without a tuner with an acceptable SWR. The

Windom being sold by K4ABT uses a 4:1 balun and the feed-point is at a slightly different location. That one is shown below.

Figure 22. Windom Dipole (Fritzel Type)



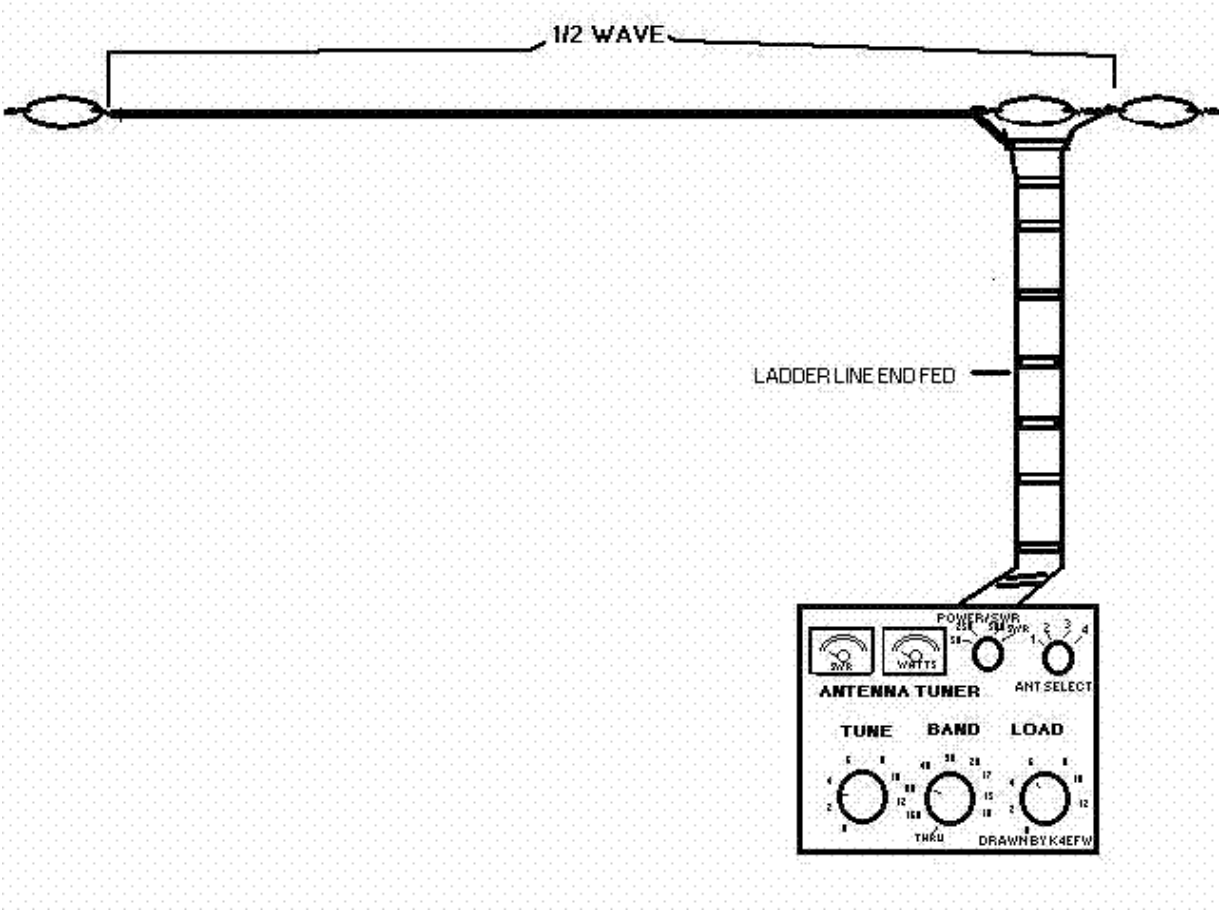
The difference between the Windom antenna sold by K4ABT and the original Fritzel is the difference in the offset of the feed-point. Since the K4ABTversion uses a 4:1 balun, it appears his is fed at the 200-ohm point, and the original Fritzel is fed at the 300-ohm point. On any resonant dipole, the lowest feed-point impedance is found at the center. As you place the feed-point offset toward either end, the impedance gets higher. The highest feed-point impedance occurs at the end of the dipole.

XI. END-FED ANTENNAS

1. End-Fed Zepp

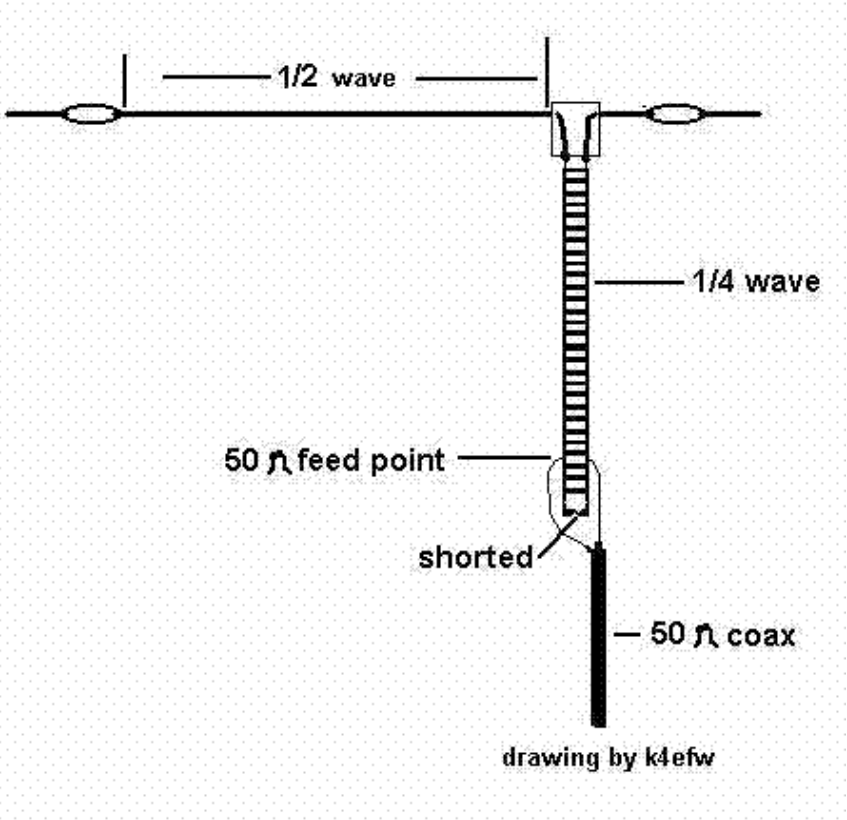
A half-wave resonant antenna can be fed from its end. When fed this way, it is also known as an end-fed zepp. An end-fed zepp will work on its fundamental frequency and on odd and even harmonic frequencies. The name "Zepp" goes back to the days of dirigibles or Zeppelins, which used trailing wire antennas that had to be fed at one end. The end of a half-wave antenna has very high impedance, and an antenna fed this way is said to be voltage fed. Feeding a half-wave resonant dipole in the center means it is current fed. The normal way of feeding the end-fed antenna is with ladder-line. One side of the ladder-line is connected to one end of the antenna and the other side of the ladder-line is connected to nothing. To secure the unconnected side of the ladder-line, it is connected to a short wire running between two insulators. Since the antenna is connected at its high impedance point, no current flows into an antenna, but there will be a large current in the center of this antenna. No current flows from the open side of the feed-line because it is at a zero current point.

Figure 23. End-Fed Zepp



The end-fed zepp can be matched by cutting the ladder-line to a quarter wavelength with the bottom end of the ladder-line shorted. A certain distance above the short is a 50-ohm feet-point and it can be fed directly with coax. MFJ is marketing antennas of this type made for single bands, and they are selling the parts separately so you can build your own. You will have to find the 50-ohm point by trial and error. This method of feed makes it a single band antenna.

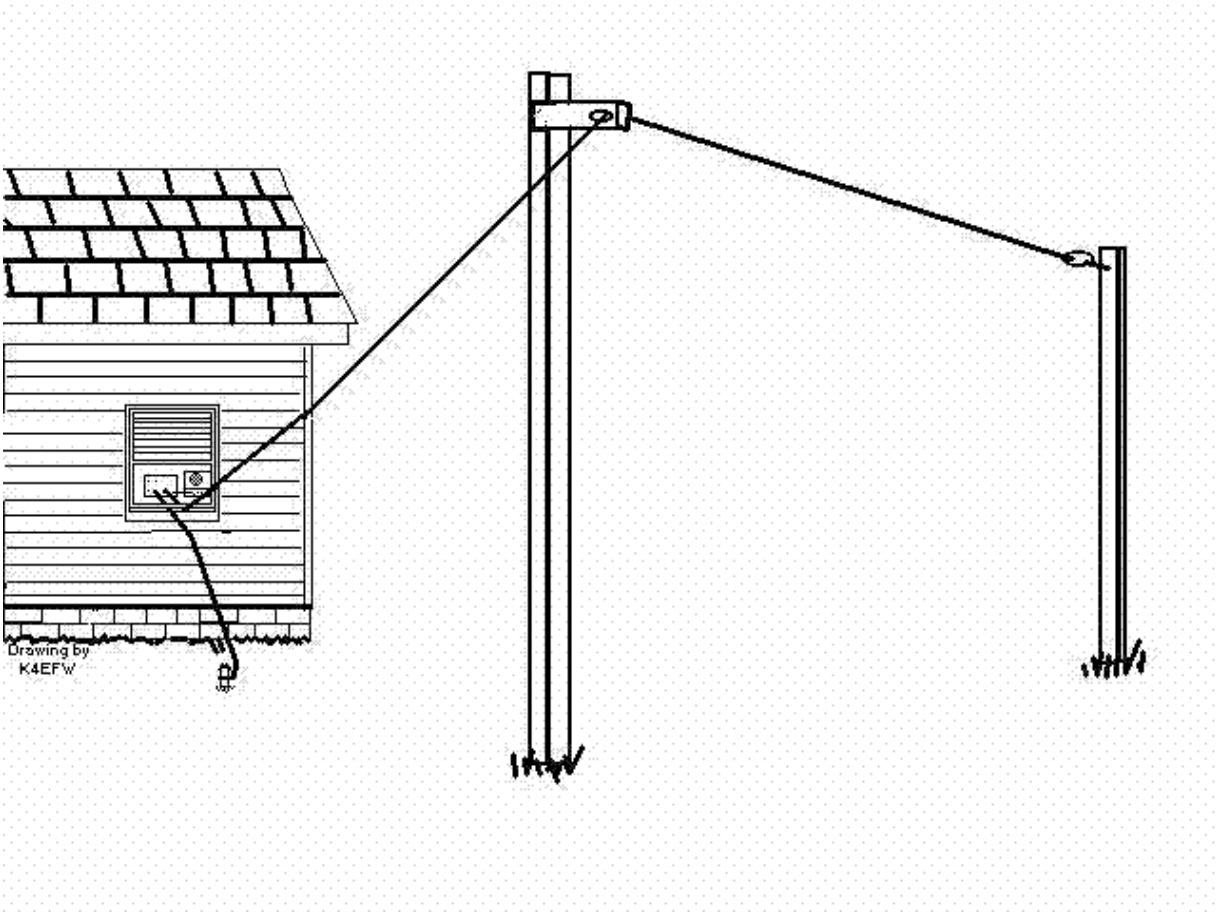
Figure 24. Alternate Method of Feeding an End-Fed Zepp



2. End-Fed Random Length Antenna

Below is another end-fed antenna made from a random length of wire connected to the back of the tuner. The wire then exits the shack and goes to a high support where it then runs horizontally to another high support. The tuners groundside must be connected to a good RF ground, since a poor ground causes high losses. This antenna is commonly called a "long wire." Since the end of the antenna comes in the shack, you will be exposed to high levels of RF. In addition, this type of installation may cause RF to be picked up in the microphone, noted by distortion. The feed-point of the long wire being connected directly at the output of the tuner can have an impedance of a few ohms to a thousand ohms depending on the antennas length. If the wire is cut to a multiple of a half wave at the lowest frequency, the system will be efficient since it is fed at a voltage point and very little current flows into the ground. This antenna is really a variation of an inverted-L fed directly without a feed-line from the tuner.

Figure 25. End-Fed Random length or Long Wire Antenna

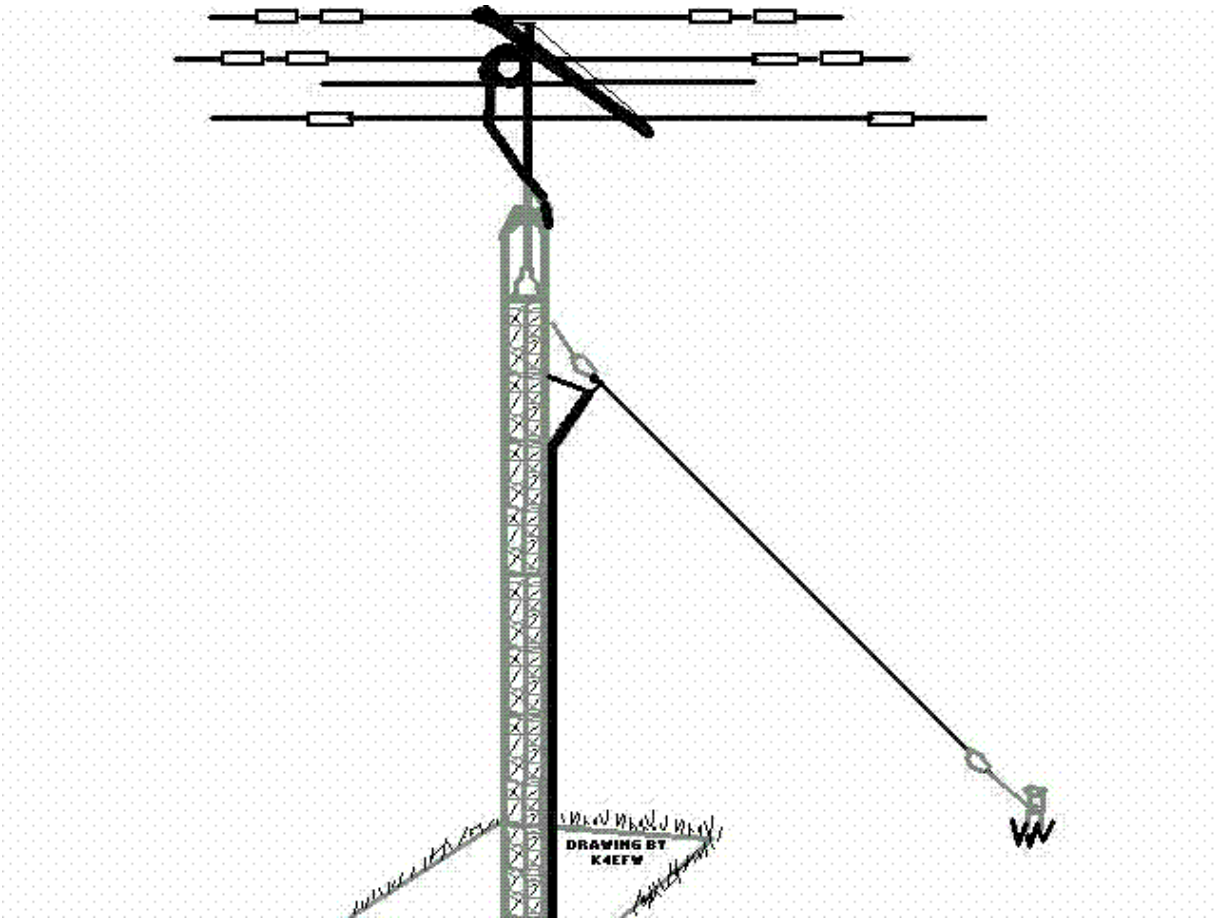


XII THE HALF SLOPER

1. The Half-Sloper

The half sloper is an antenna that is hard to categorize, since it is not a sloping dipole and it is not a vertical. The half sloper is half of a sloping dipole. To make one of these antennas, cut a quarter-wave radiator by dividing 234 by the frequency in MHz and tie an insulator to both ends. One insulator is tied near the top of a tower and the radiator wire is run down toward the ground. Coax is split into its center conductor and shield, and it connects across the insulator at the tower. The center conductor of the coax is tied to the quarter wave radiator and the shield is grounded to the tower. This means the tower is acting as the missing half of the dipole. It is a difficult antenna to get a good match because the height above ground of the feed-point and the angle of the slope affect the impedance. Some users of this antenna say to mount the feed-point at 45 feet up on the tower and have a beam antenna on the tower above the feed-point to use as a counterpoise. Other users say you must find the 50-ohm point on the tower, which is a tedious task. It has also been said, "Some installations work super, while others do not work well at all." The half-sloper is used almost exclusively on 80 and 160 meters. The Alpha-Delta half sloper was tried here and its performance was disappointing. The signal from it was down a least 10 dB below a dipole and the SWR wasnt low enough. The half sloper is mostly vertically polarized and it is directional toward the slope.

Figure 26. Half-Sloper



XIII VERTICAL ANTENNAS

1. Why Verticals Are Used

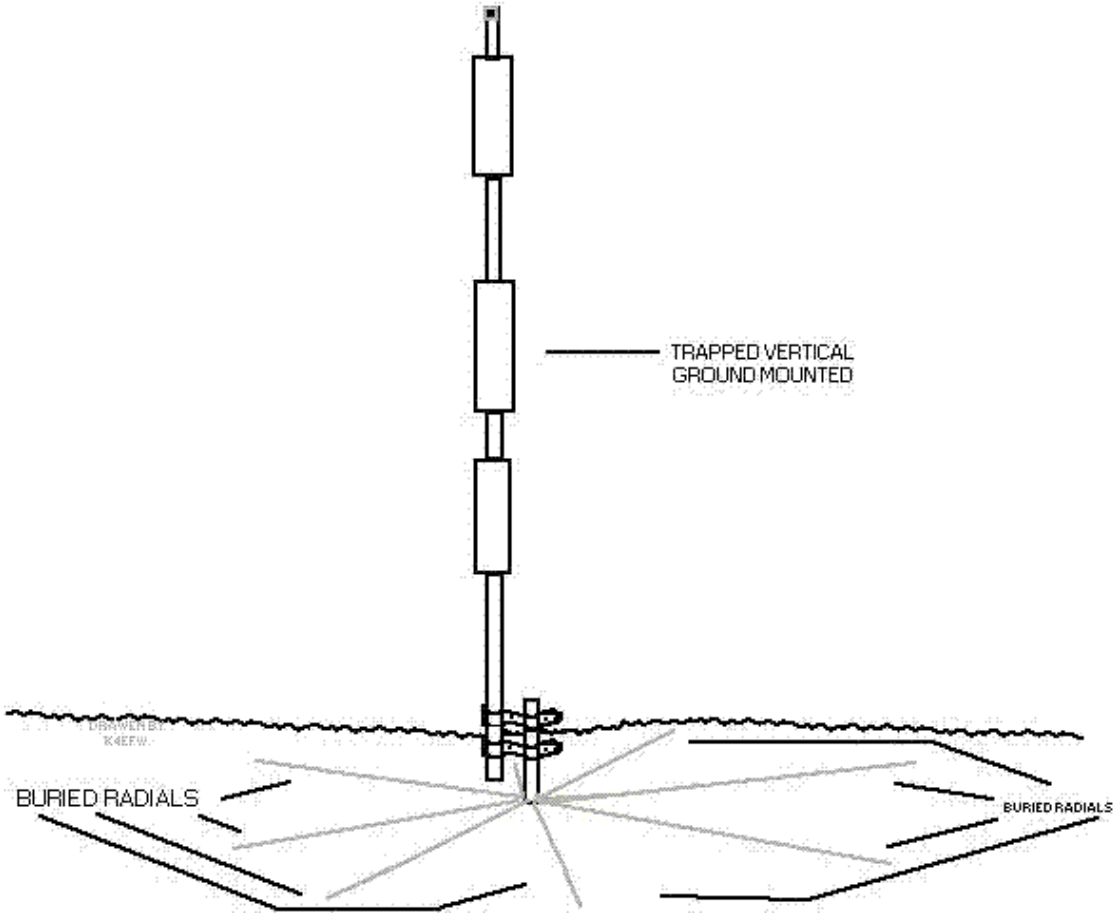
Vertical antennas have the radiator mounted at right angles to the earth. The vertical is used whenever you desire to radiate your signals in all directions at a low angle. Low angle radiation is needed to work DX effectively. Radio waves traveling to the ionosphere where they are reflected need to hit the ionosphere at a point near the horizon in order to reflect farther around the curvature of the earth. In order to get a dipole to radiate a strong signal at low angles, it has to be more than a wavelength above ground. A low dipole is not particularly a good DX antenna for 80 and 160 meters. However, the average dipole at modest heights will outperform any ground-mounted vertical having a poor ground system. Vertical antennas work very well at low frequencies such as the broadcast band, but the ground losses increase as we move higher and higher in frequency (Refer to section V concerning ground-wave propagation). It is very difficult to get a good ground for a ground-mounted vertical unless you live next to salt water. Vertical antennas, because they are unbalanced antennas, do not need baluns. They are normally fed with coax.

If a ground mounted, quarter-wave vertical is all you can put up at your location (QTH), then use it. However, it will be a mistake to put up this antenna if you are not be able to have a ground radial system and are able to put up a dipole. Most ground mounted quarter-wave verticals manufactured today are trapped in order to work multiple bands.

The ground-mounted vertical also needs to be put out in the clear away from RF absorbing objects. These facts do not apply to half-wave verticals, which are in themselves different animals, nor do they apply to high quarter-wave verticals using elevated radials.

The approximate length of a full-sized resonant quarter wave vertical can be found by dividing 234 by the frequency in MHz. Note: 234 is half of 468, the number we used to calculate the length of a half-wave antenna. The actual length for resonance may be a little different from what you calculate, because of the diameter of the vertical element. Trapped verticals are physically short of a quarter wave in length because the traps load them. The vertical is fed at one end at the bottom where it is insulated from the ground. The center conductor of the coax connects to the vertical element and the shield is connected to the ground system.

Figure 27. Ground Mounted Trapped Vertical



2. Disadvantages of Using Quarter-Wave Verticals

The most obvious disadvantage of using any vertical antenna is on 80 meters it has less than optimum high-angle radiation needed to work stations within a few hundred miles. Ground-mounted quarter-wave verticals use a ground system for the other half of the antenna and the ground system losses can be very high. The ground wave signal should eventually radiate in space at angles at the horizon, but since there are very high losses in the ground wave at amateur frequencies, a ground-mounted vertical has almost no signal down near the horizon. At angles below 10 degrees, the signal will be greatly attenuated.

A ground-mounted quarter-wave vertical with an ideal ground should have an impedance of 35 ohms resistive. If you were to measure its impedance, and it measures 60 ohms resistive on an antenna analyzer, it means it has a loss resistance of 25 ohms. Moreover, that loss resistance is mostly in the ground system. Under these conditions, only 58% of the power will radiate as RF, although you will have a 1.3:1 SWR. Forty-two percent of the power will be turned into heat by the loss resistance. With the feed-point being at ground level, some more loss comes from the radiated wave being absorbed by power lines, trees, and buildings with its associated wiring. That loss does not show up in antenna analyzer

measurements.

The best ground system for a ground-mounted vertical is 120 wires, called "radials," radiating from the feed-point like the spokes of a wheel. These radials need to be a quarter wave long. At the feed-point, the radials are bonded together and are fed from the shield side of a coax cable. Not many amateurs have the resources to build such a ground system. Many short radials will be more effective than a few long ones. When using a ground mounted vertical, many hams drive an 8-ft. ground rod into the earth for their ground system. The ground losses are very high in that case. Using a ground rod for the ground system of a vertical antenna confirms the old adage: "Verticals radiate poorly in all directions."

To eliminate ground losses, you can use an elevated quarter-wave vertical with an elevated ground system called a "ground plane." The ground plane vertical, as it is called, needs to be mounted high enough to prevent the return path from coming back through the earth ground. Ground plane verticals need to be mounted above nearby objects that absorb RF. They will be nearly 100% efficient if they are high enough. The ground plane consists of two or more radials, but most ground planes have three or four. The ground plane radials do not have to be resonant, but should be at least a quarter wave long. An elevated ground-plane vertical will be more effective for working DX than a dipole.

3. Long and Short Verticals

Verticals can be less than a quarter wave in length. They can be loaded by coils or linear loading sections or a short vertical can be fed directly with a tuning unit at the feed-point. The loss resistance in a short vertical may be appreciable. Since the radiation resistance is very low at the feed-point of a short vertical, the current at the feed-point will be very high. The more current that flows into loss resistance, the higher the loss will be. Any coils used in the tuning unit and for loading should be made of as heavy a conductor as possible, since these can cause appreciable loss when the current is high. This is also true for the ground system. The loss described here is called "I squared R loss", which means the loss in watts is found by multiplying the current times itself and then multiplying that answer by the loss resistance. That means if the current into a lossy antenna system is doubled, the power lost in watts is increased four times. Making a vertical very short and tuning it to resonance with an inductor will also result in an antenna with a very narrow bandwidth.

A more subtle loss of energy in very short vertical antennas is coronal discharge from the tip end of the vertical. Corona occurs when the voltage is very high at the end and electrons flow out into the air. This can be visible at night if the transmitter power is high and you are at a high altitude. Power is lost from the antenna when corona is produced because corona is a form of light and light is another form of energy.

In 1973 while we were working for radio station WWNC in Asheville, North Carolina, a trapped vertical for 10 through 80 meters was erected. The length of the antenna was only about 25 feet. A loading coil near the top made it resonant on 75 meters. The ground system was the metal body of a 75-foot long mobile home. Fair reports were received from this set-up. The reports were not bad because of our having a good ground. One night, while working 75 meter SSB, one of the neighbors came over and said, "Youre tearing up my TV." Checking all of the inside connections proved they were tight. Our wife keyed up the transmitter while we made a trip to the antenna to check the connection there. Before arriving there, looking up, we saw blue fire coming off the end of the vertical. The corona was responsible for the television interference (TVI). It was visible because Asheville is at a relatively high altitude and the transmitter was running 700 watts. An inverted-V was put up, the TVI disappeared, and better signal reports were received.

You can realize up to a 1.5 dBd gain from a vertical antenna by making it longer than a quarter wave,

but there is a limit to how long to make it and still get low angle radiation. That limit is 5/8th-wave. To find the length of a 5/8th-wave vertical, divide 585 by the frequency in MHz. For example, to calculate the length of a 5/8th-wave vertical for 20 meters (14.000 MHz) divide 585 by 14.0. It equals 41.786 feet or approximately 41 feet 9.5 inches. A tuning unit will be needed at the feed-point of this antenna, as the impedance of a 5/8th-wave antenna is low and high current will flow into it. A tuning unit will usually have enough bandwidth to cover the entire band on each band of 20 meters and higher. A tuning unit is also called a matching network. It is similar to an antenna tuner, but has fixed inductors and capacitors. Tuning units for 80-and 160-meter verticals will cover only a portion of the bands. Outside the bandwidth limits of the tuning unit, you can use the tuner at the transmitter end. Radials or ground planes are needed for a 5/8th-wave vertical and they need to be a quarter wave long.

The impedance of a half-wave antenna is high if fed at its end. An end-fed half-wave vertical will have a small amount of gain over a quarter-wave vertical. This antenna does not have the ground losses a quarter-wave vertical has because it is fed at a high impedance point and the current flowing into the ground is negligible. Commercially made resonant half-wave trapped verticals now on the market are end fed at the bottom. A built-in matching network is found at the base, and several very short radials are mounted below the feed-point to de-couple RF from the feed-line. These antennas should be mounted as high as possible away from RF absorbing objects. Because the ground losses are lower, the half-wave vertical will outperform a quarter-wave vertical by several dB and in many cases many dB.

4. Unscientific Observations of Verticals

At our home, an old Hy-Gain trapped quarter-wave vertical for 40-10 meters was erected in 1961. It was mounted on the roof and had two quarter-wave radials for each band. It worked, but it was never compared to another antenna. It gave the impression it was a mediocre antenna. Other antennas replaced it.

One time in 1964, a grounded 60-ft tower was shunt fed as a vertical on 75 meters. Without having any radials, the transmitted signal was 10 dB weaker on this vertical 650 miles away in New York than on the inverted-V.

In 1969, a 4-band trapped vertical was put up on the top of a 60-ft tower. A 15-meter 4-element yagi under it was used for the ground plane. It was probably the best vertical installation we ever tried. It was good because it was high and in the clear and the 15-meter yagi made a good ground plane.

While we are on 80 meters, a ham 200 miles away frequently joins in the roundtable. He uses a trapped quarter wave vertical with a chain link fence as the ground. Several of the others are also 200 miles away run the same power. His signal is 10 to 20 dB below everyone elses on the frequency. It is good there are no interfering signals or noise or he will not be copied.

Another ham uses a Hy-Gain Hy Tower vertical with 3 ground rods as the ground system. According to our S-meter, his signal is 40 dB down below those of the other guys.

Charlie, AD5TH, works 40 meters using a Hustler 5-BTV vertical ground mounted with 72 quarter-wave radials. He has an outstanding signal for a ground-mounted vertical. His installation is out in the clear away from RF absorbing objects. He says, because of antenna restrictions at his location, it is the only antenna he can put up.

Another ham friend, N2HGL, has both a dipole and a half-wave trapped vertical on 40 meters. At a location 160 miles away, he is 10 dB stronger on the dipole, but he is equal in strength on both antennas in Indiana 600 miles away. This comparison shows the superiority of the half wave vertical over the

quarter-wave one because his signal with the half-wave vertical was equal to his signal from the dipole. If he were using a quarter wave vertical, we would expect his signal would be better on the dipole in Indiana. It also demonstrates the superiority of a dipole over a vertical for working short distances.

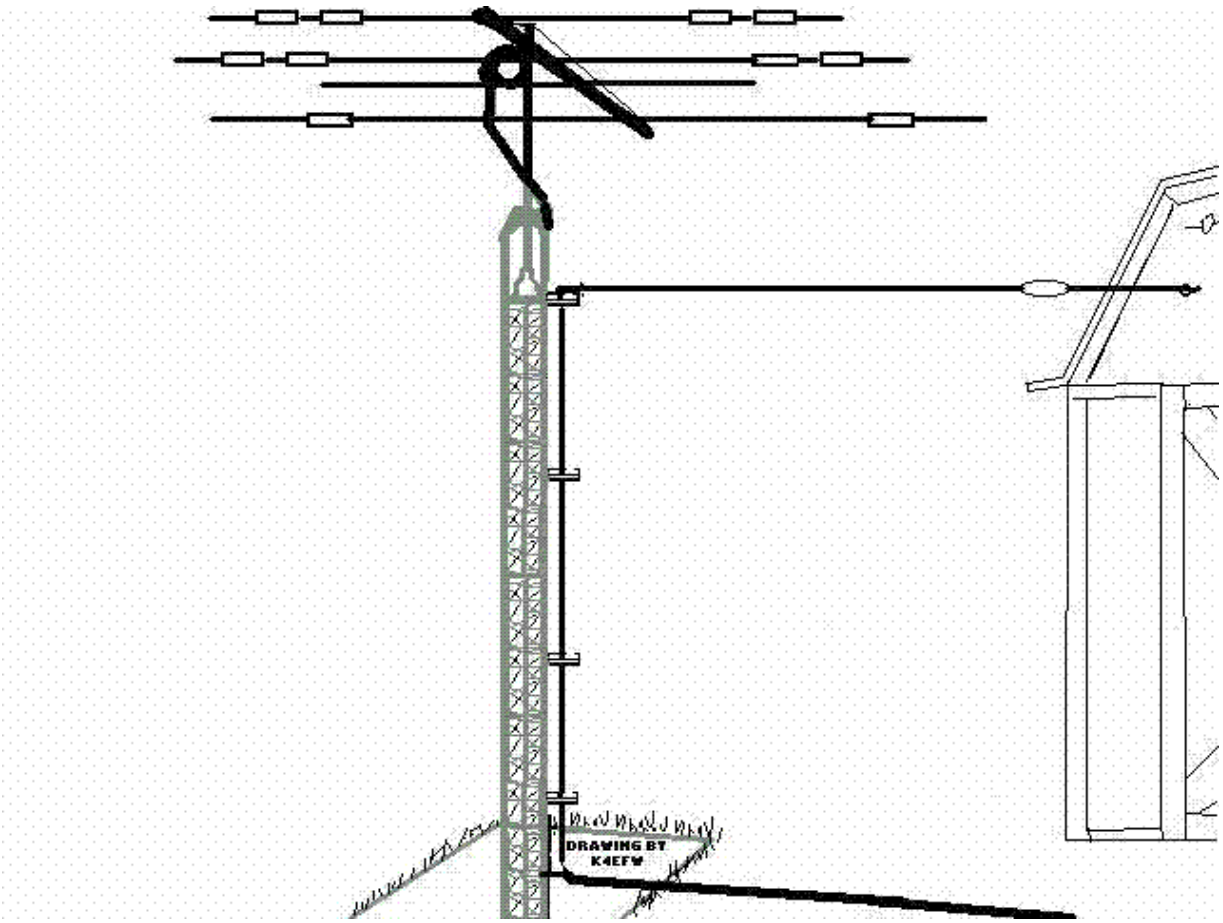
Bill, W4ZQL, runs a ground-mounted SteppIR vertical. He lives beside a salt-water river in Florida that he uses for a ground. He puts out a very good signal on 40 meters. No ground losses!

5. The Inverted-L Vertical

The inverted-L antenna is a wire vertical antenna with part of the top end bent horizontally. It resembles an "L" turned upside down. The inverted-L is used to reduce the height required by a vertical and still keep the antenna resonant and full sized. It is fed at the end at ground level the same way a ground mounted vertical is fed, and all the losses we described for a ground-mounted vertical apply here. Some current flows in the horizontal part of the inverted-L and for that reason, it has both strong vertical and weaker horizontal polarization. If you make it a half-wave antenna, you wont need a good ground because negligible current flows into the ground. A half-wave inverted-L antenna needs to be fed with 50-ohm coax and a tuning unit.

An inverted L for 160-meters is usually made of wire one-quarter wavelength long or about 127 feet. It runs vertically from near ground level to the top of a support, perhaps 60 or 70 feet. Then the end runs horizontally and is tied to a nearby support. The antenna is coax fed at ground level between the vertical section and ground system across some type of insulator. A matching network at the feed-poimt will be required to match it if the impedance is not equal to 50 ohms.

Figure 28. Inverted-L



The picture shows an inverted-L running up the side of a tower. The feed-point is at ground level with the center conductor of the coax attached to the bottom end of the wire. The coax shield connects to a ground system of radials. The total length of wire used in this antenna is half of what is needed for a dipole since the other half of the antenna is the radial ground system. The inverted-L is used mostly on 160 meters, but some have built them for 80 meters. The inverted-L antenna can also be cut for a half-wave to reduce ground losses.

6. Vertical Mobile Antennas

We have heard many good signals from mobiles, many being stronger than those from hams using ground mounted quarter-wave verticals. The mobile antenna, being so short, has a large capacitive reactance. A coil is inserted in the antenna to provide an equal amount of inductive reactance to make it resonant. As we said in the paragraph on short verticals, a coil of this type, carrying a large amount of antenna current, causes some loss resistance in the system. To reduce losses in the coil, wind it with a conductor as large as practical. (Thats exactly what some mobile antenna manufacturers have done.) The sources of loss in mobile antennas are in the coil losses, losses in the conductors making up the radiating part of the antenna, corona discharge, and the ground loss from the vehicle on which its mounted. However, because of the large amount of metal in the body of the vehicle, the ground losses are not as high as the losses from ordinary ground mounted verticals. Matching transformers are now available that step down the impedance of 50-ohm coax to the very low impedance of the loaded vertical. Good advice is to use the transformers rather than to rely on the internal tuner of the transceiver.

Some low priced single-band mobile antennas are constructed by using a polymer shaft and a small gauge wire encapsulated in polymer material running beside the shaft. The loading coil made of the same wire is also encapsulated in the polymer. The small wire, because of its size and because it carries a large RF current, will lose a lot of power by becoming hot. This type of mobile antenna is rated for 200 watts. If the wire didnt get hot, there would be no power limit.

All mobile antennas have corona loss and for such, there is no remedy. Most amateurs, because they cant see it, dont believe its there. Corona will not be visible unless you run high power and it is dark.

Ground losses from the vehicles body diminish with increasing vehicle size. This is why 18-wheeler hams have such big mobile signals. To diminish the ground losses on any mobile installation, you should use as large as a conductor as possible to bond the coax shield to the vehicle body. All metal parts of the vehicles body, fame, and drive system need to be bonded together with heavy ground straps. To make the mobile antenna system more efficient, use an antenna with an adjustable inductor and use as long a "stinger" as practical above the coil. You will increase the radiation resistance by using a longer stinger, and then the loss will be less because you will require less coil inductance. The ratio of radiation resistance to loss resistance becomes larger by raising the radiation resistance and reducing the loss resistance. As we said earlier, the efficiency of any antenna system is found from the ratio of radiation resistance to total resistance, or radiation resistance divided by total resistance times 100%. The total resistance is equal to all the loss resistances plus the radiation resistance.

The latest development in HF mobile antennas is motor driven variable inductors. These antennas are known as "screwdriver antennas." The name refers to the electric screwdriver motors used to vary the inductance. A control cable is run from the motor to a switch at the operators position so it can be tuned from the operators seat in the front of the vehicle. Because a mobile antenna has a very narrow bandwidth, you will have to tune it often as you move frequency (QSY). It hasnt been many years since we had to get out of the vehicle to make inductor changes or make changes in the length of the stinger when the frequency was changed.

Mobile antennas for 20 through 10 meters do not require the care in installation that is needed for 160, 80, and 40 meters because the length of a mobile antenna becomes closer to a quarter wave as you move to higher bands. The radiation resistance increases on each higher band. While moving to higher bands, less inductance is needed to tune the antenna, and that lowers the loss resistance. A 96-inch mobile whip is just a couple of inches short of being a quarter wavelength on 10 meters and a loading coil is not needed there. The band that has the least mobile antenna efficiency is 160 meters. If you reach a radiation efficiency of 2% on 160 meters on your mobile installation, you will be doing well.

Below is some information concerning mobile antennas, which was received in an email. There was a 75-meter mobile "shoot-out" in California. (A shoot-out is an event where a group of hams gets together and compares signals radiated from various antennas.) Supposedly, equal power was applied to each antenna under test. Apparently, some type of field strength meter was used. A screwdriver antenna and a bug catcher, both with top hats, were used as the standard by which other antennas were compared because they put out equal signals. The other antennas are measured in how many dB they were below the standard. Here are the results of that test, and because it is hearsay, the accuracy of these figures is not guaranteed, but they do compare to what we have observed.

Screwdriver/bug catcher with top hats 0 dB reference

Screwdriver/bugcatcher without top hats -3dB, -50%

Hustler -7 dB, -80%

Outbacker -9 dB, -88%

Hamstick -12 dB, -94%

Whip with autotuner -14 dB, -96%.

The efficiency of the best 75-meter mobile antenna is from 5% to 10%. In using the best mobile antenna on 75 meters, a 100-Watt mobile rig will radiate 10 Watts at most. This means that a Hamstick being fed with 100 Watts will radiate only 0.6 watts, which is 6% of 10 Watts. Ninety-nine and four tenths Watts will be converted to heat. The person sending this information said it was published on the Internet in some news group. Again with good band conditions, it is amazing how little signal can be used to communicate.

The things that increase the efficiency of mobile antennas are

Place the loading coil about half way from the feed-point to the antenna tip. Efficiency decreases if you put the coil above or below this point.

Mount the antenna as high up on the vehicle as possible. This reduces the ground losses because it reduces the capacitance of the antenna to ground.

Use a loading coil with a Q as high as possible. See the ARRL Handbook for a discussion of coil Q.

Make the antenna as long as possible. Note: long antennas are prone to strike tree limbs and bridge overpasses.

Increase the size of the mast between the loading coil and feed-point.

Put a capacity hat above the loading coil. The capacity hat reduces the number of coil turns needed to resonate the antenna.

Make the coil with as large a diameter wire possible. This decreases the coil loss, which is a large part of the total loss of a mobile antenna.

Any changes made in the antenna system that raises the radiation resistance will increase the efficiency.

XIV. ONE-WAVELENGTH SINGLE LOOP ANTENNAS

1. The Horizontally Oriented Loop

To calculate the length in feet of any one-wavelength loop, divide 1005 by the frequency in MHz. Horizontally oriented one-wavelength loop antennas have become very popular on 160, 80, and 40 meters and it is one type of NVIS antenna. (NVIS stands for "near vertical incidence skywave" because of its high angle radiation pattern.) It is claimed by its users that the loop antenna is quieter than other antennas. This is because it doesnt pick up the noise from power lines, thunderstorms, etc., coming in at low angles. These antennas radiate on their fundamental frequencies with a broad pattern straight up to put a strong signal for nearby contacts. Recently published articles on this type of antenna have called them "cloud warmers." There are other types of antennas called NVIS antennas other than loops. They are dipoles at low heights or dipoles with parasitic reflectors placed under them to cause the signal to radiate mostly straight up. The NVIS antennas have an advantage in working nearby stations because you dont get the static noise and interference from far distances. They are definitely not DX antennas. An article on NVIS antennas appears in the December 2005 QST.

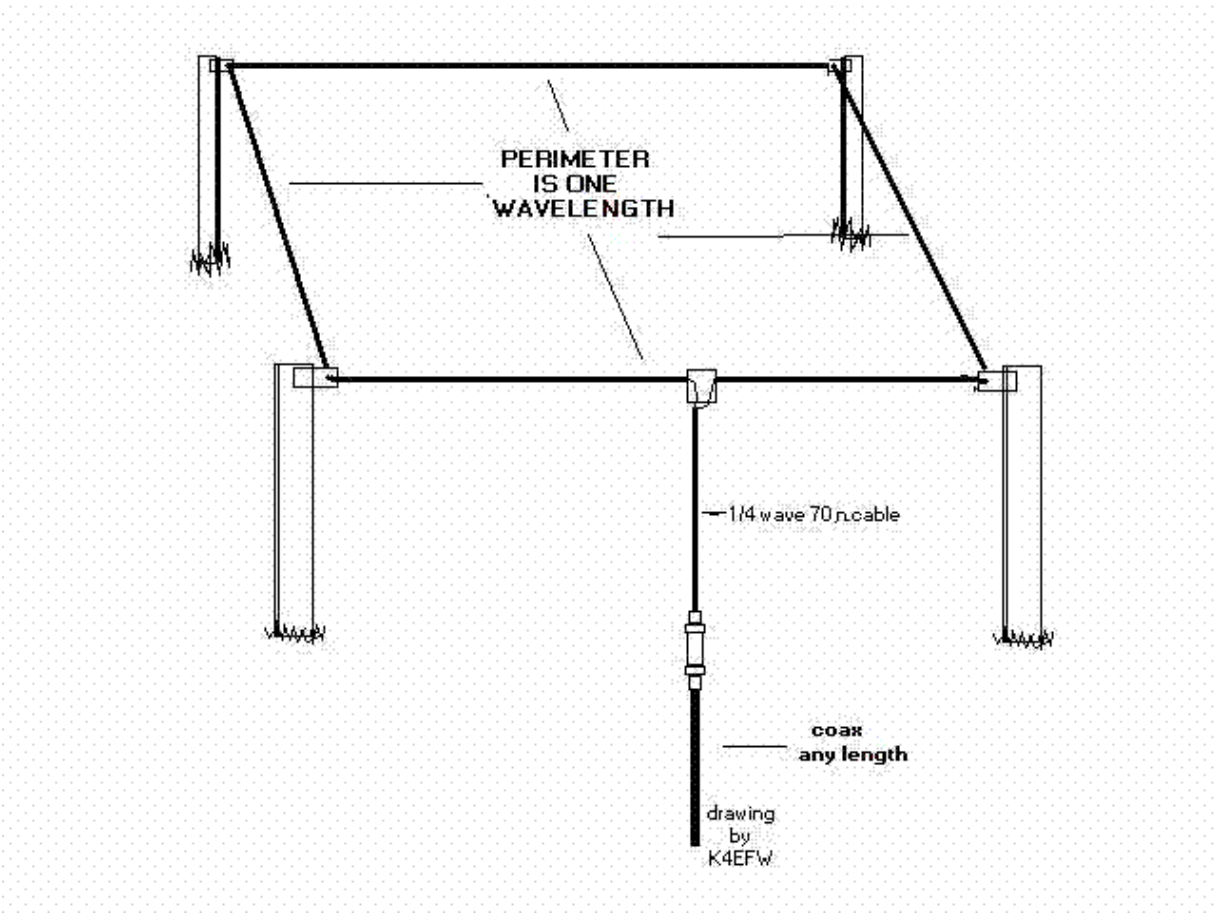
On their fundamental frequencies, horizontally oriented loops take up half the horizontal distance as a half wave antenna for that band. Loops are two-dimensional antennas having depth as well as breadth. There are two loop configurations: The square loop and the triangle loop. Some hams have pulled the loops out in irregular shapes to fit where the supports are located. The only advantage in using a rectangular loop instead of a square loop is to take up less horizontal space. This is true because the gain of a rectangular loop is diminished below a square loop. The area enclosed by the perimeter of the loop determines the gain of a loop. A circular loop has the most enclosed area, but it requires an infinite number of supports. The gain of a loop comes from the loop having two maximum current points separated by a distance of one-quarter wavelength. From here on we will call a horizontally oriented loop a horizontal loop.

We also modeled the gain of the horizontal loop for the 80-meter band over real ground. The maximum gain occurs with the loop at 7 meters or about 25 feet above ground. Mind you, this gain is straight up from the loop. At that height, its gain is about 9.25 dBi and that equates to about 7 dBd in free space. The gain of the loop diminishes slightly as the antenna is raised. The feed-point radiation resistance at 7 meters height is 35 ohms resistive and 0.0 ohms reactance and you do not need a matching section of 70-ohm coax. At a height of 10 meters or about 33 feet, the radiation resistance rises to 63.5 ohms. There the SWR will be 1.27:1, if it is fed directly with 50-ohm coax. At 15 meters or about 50 feet, the radiation resistance rises to 118 ohms and a 70-ohm matching section will be in order. The gain drops to a little less than 7 dBi at that height. These figures may or may not be applicable to your QTH, because your soil conductivity may be different from the soil we used to model it. As you can see from the above numbers, the feed-point resistance rises as the loop is raised.

The horizontal loops also are used on their harmonic frequencies. The loop with more gain and a

superior pattern is a two-wavelength loop. An 80-meter loop is a two-wavelength loop on 40 meters. The two-wavelength loop has a lower angle of radiation, but is a very large antenna for 80 meters. At 3800 kHz it has a perimeter of about 530 feet. A two-wavelength loop is not an NVIS antenna. Using coax with a tuner is not an ideal way for working a loop on its harmonic frequencies. This is because of the high SWR in the coax on some bands will cause high loss. For example, an 80-meter loop fed on 40 meters will have an SWR of 8:1 and the SWR on 20 meters will be 49.5:1. There will be some hams who will say they get satisfactory results this way, however theory suggests they will have a stronger signal if they use a ladder-line because ladder-line has less loss. Feeding a loop antenna with ladder-line makes more sense when working a loop on harmonic frequencies.

Figure 29. One Wavelength Horizontal Loop



To realize maximum gain, make the square and triangle have equal sides. When the sides are equal, the loop has maximum enclosed area for whatever configuration you use. Other shapes will work, but the gain will suffer.

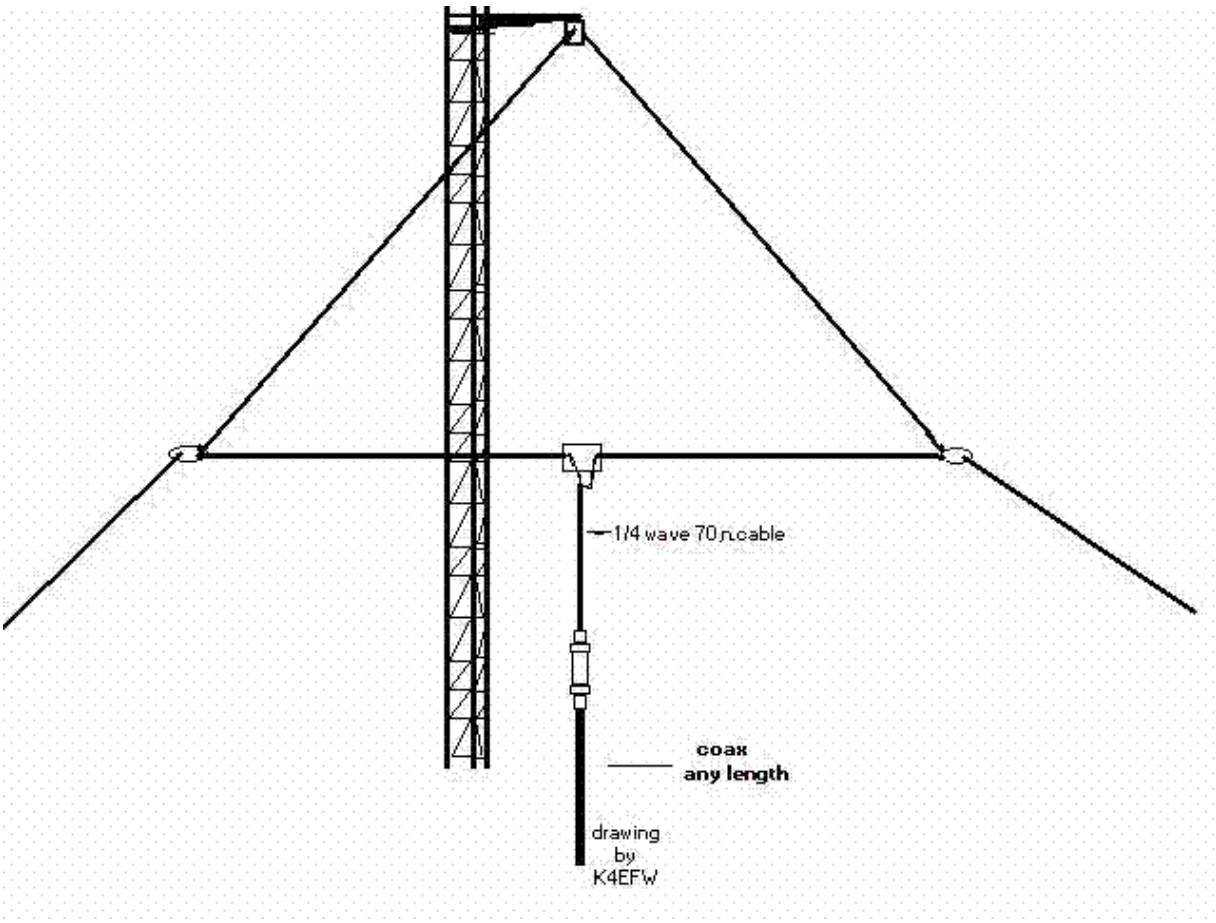
To support a square loop, you will need four supports, one for each corner. We hope you will have trees or masts in the right places. A triangular loop will need three supports. Once you have cut the single piece of wire to the right length, run the wire through as many insulators as you have corners. At each corner of the loop, put an insulator and tie the corner to a support with a rope from the insulator. To make the feed-point, connect both ends of the loop to an insulator. Strip the insulation from the outer part of the coax. Separate the shield from the center conductor. The ends of the coax are connected to the ends of the loop across the insulator. Most hams do not feed loops with a balun at the feed-point.

2. The Vertically Oriented Single Loop for 40 and 80 Meters

Vertically oriented loops radiate broadside to the plane of the loop. A horizontally polarized vertically oriented loop has both vertical and horizontal wires. From here on out, we will refer to a vertically oriented loop as just a vertical loop. When using this term, we are not referring to its polarization. If the feed-point is on one of the horizontal wires, the loop radiates horizontally polarized waves. The vertical wires radiate weaker vertically polarized waves. If the feed-point is on one of the vertical wires, vertically polarized waves will be radiated. The radiation from a one-wavelength vertical loop has both high-angle and low-angle radiation. It is a good antenna for both nearby stations and for DX contacts. It is better than a dipole for DX because the vertical loop puts out a stronger low angle signal than a dipole does.

The gain of a vertical delta loop is 4.55 dBi or about 2.4 dBd. Its feed-point impedance is about 120.5 ohms. The square vertical loop has 5-dBi gain and about 2.85 dBd and the feed-point resistance is 143 ohms. They both need to be fed with a series quarter-wave matching section of 70-ohm coax.

Figure 30. Single-Element Vertical Delta Loop



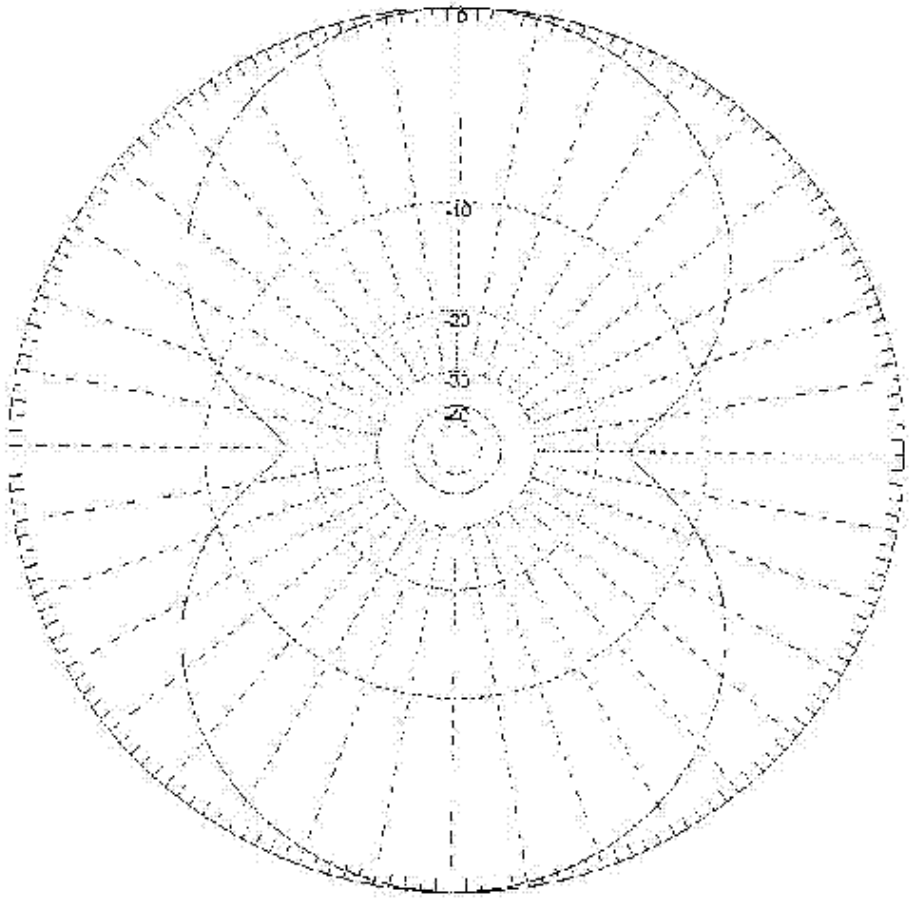
Square vertical loops need two supports. The square vertical loop needs less vertical space than the delta loop. The vertical space needed for a square vertical loop for 80 meters is 92 feet. For 40 meters the vertical space is half that. It is rare to find someone using the square vertical loop these days. The vertical delta loop is more common because it needs only one high support. The apex of a delta loop for 3500 kHz needs to be 102 feet high and on 40 meters, it needs to be 62 feet. This assumes the bottom horizontal wire will be 20 feet off the ground. In order to make a vertical loop fit on a shorter support, the sides of the loop can be reduced in length while making the horizontal wires longer. This will put the two maximum current points closer together, which has the effect of reducing the gain.

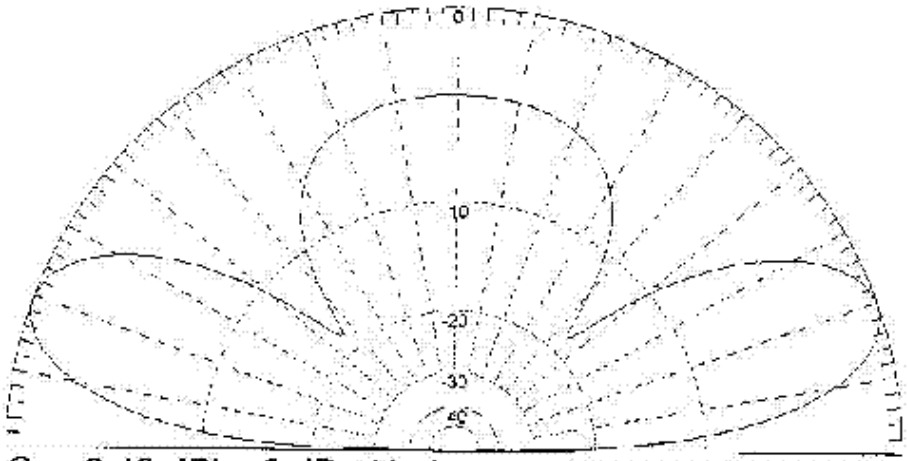
Like the horizontal loop, the formulas for finding the length in feet of these loops are the same: 1005

divided by frequency in MHz. In addition, because the feed-point resistance is nearly the same as horizontal loops, quarter-wave matching sections and other methods can be used to feed the vertical loops. The vertical loop is not as sensitive to height as the horizontal loop. Both vertical square loops and vertical delta loops can be operated on harmonically related bands. (See Figure 32).

Figure 31. Radiation Pattern of a 30-Meter Delta Loop on 30 Meters.
The Bottom Wire is at 18 Meters above Ground.

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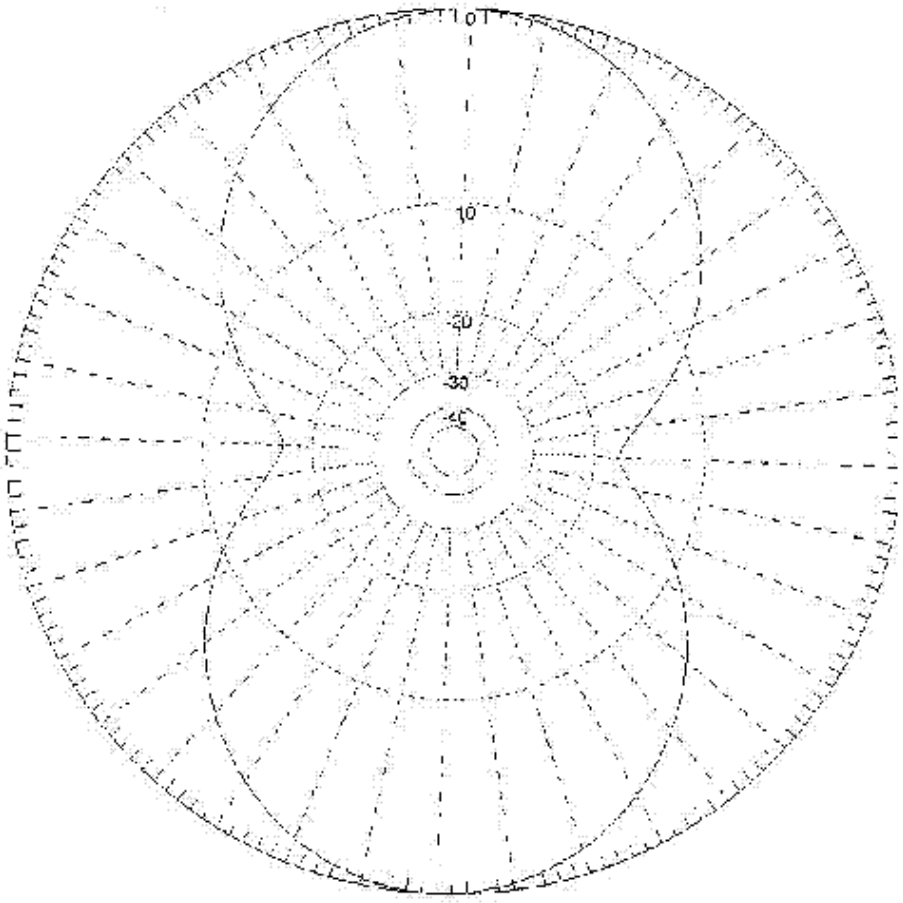


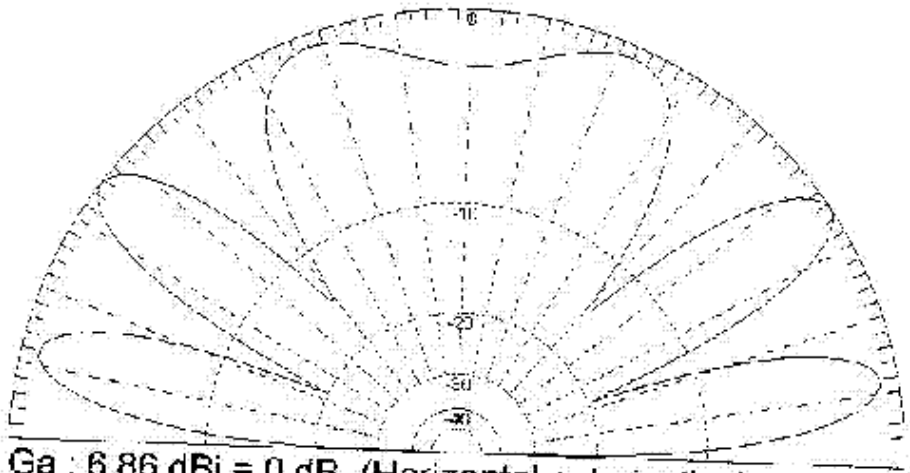
Ga : 8.43 dBi = 0 dB (Horizontal polarization)
F/B: 0.00 dB; Rear: Azim. 120 dg, Elev. 60 dg
Freq: 10.100 MHz
Z: 101.904 - j2.068 Ohm
SWR: 2.0 (50.0 Ohm), 5.9 (600 Ohm)
Elev: 19.6 dg (Real GND :18.00 m height)

The horizontal pattern shown above demonstrates that the 30-meter delta loop has a bi-lobal pattern broadside to the plane of the loop. The vertical pattern below the horizontal pattern shows both high angle and low angle radiation. The angle of maximum radiation is at 35 degrees above the horizon. The angle of radiation straight up is only down about 1.5 dB. This is pattern demonstrates the vertical delta loop is good for both nearby stations as well as DX.

Figure 32. Radiation Pattern of a 30-meter Delta Loop on 15 Meters

MMANA-GAL v. 1.0.0.65





Ga : 6.86 dBi = 0 dB (Horizontal polarization)
F/B: 0.00 dB; Rear: Azim. 120 dg, Elev. 60 dg
Freq: 21.200 MHz
Z: 544.350 + j314.303 Ohm
SWR: 14.5 (50.0 Ohm), 1.7 (600 Ohm)
Elev: 35.4 dg (Real GND :18.00 m height)

XV. DIRECTIONAL BEAM ANTENNAS

1. The Monoband Yagi

Between 1926 to 1929, Shintaro Uda and Hidetsugu Yagi developed a beam antenna that had sharp directivity and high gain. Later, work was done primarily by Mr. Yagi and yagi was the name given to the antenna until finally recognition was given to Mr. Uda. Its proper name is the Yagi-Uda Array. Most hams call it a beam.

A monoband yagi is the name given to a yagi for a single band. The performance of any commercially made monoband yagi is touted to have its dimensions tuned for maximum performance. As you will see later, this is not always the case. Monoband yagis being sold today are much improved over older designs because of computer modeling programs available.

The yagi is made of two or more aluminum elements mounted on and perpendicular to a boom. Hams use antenna rotors to turn the antenna in the direction of the station they want to work. However, there are wire beams, fixed in one direction, mainly on 80 meters, suspended between trees or other supports. Most high frequency beam antennas used by hams are in the horizontally polarized configuration, which means the elements are parallel to the ground. CB beam antennas and some two-meter beams are vertically polarized with the elements at right angles to the ground (See Section III).

A 2-element yagi has a gain around 3 to 4 dBd. A two-element yagi will have a driven element with either a reflector or a director. The driven element is the only element receiving power directly from the transmitter. The reflector and directors are called parasitic elements because they receive power from the driven element by inductive coupling.

The 3-element yagi will have a gain of approximately 5 to 7 dBd or 7 to 9 dBi depending on its boom length. A three-element yagi has one reflector, one driven element, and one director. Because the yagi has a low radiation resistance, a matching system is located at the driven element feed-point. The ratio of the radiation off the front compared to the radiation off the back is called front-to-back ratio. Front-to-back ratio and forward gain are factors to be considered in choosing a yagi design. Both measurements are given in dB. All yagis have a good front-to-side ratio, with the signal off the side being 50 dB below the front.

Figure 33. Three-Element Yagi

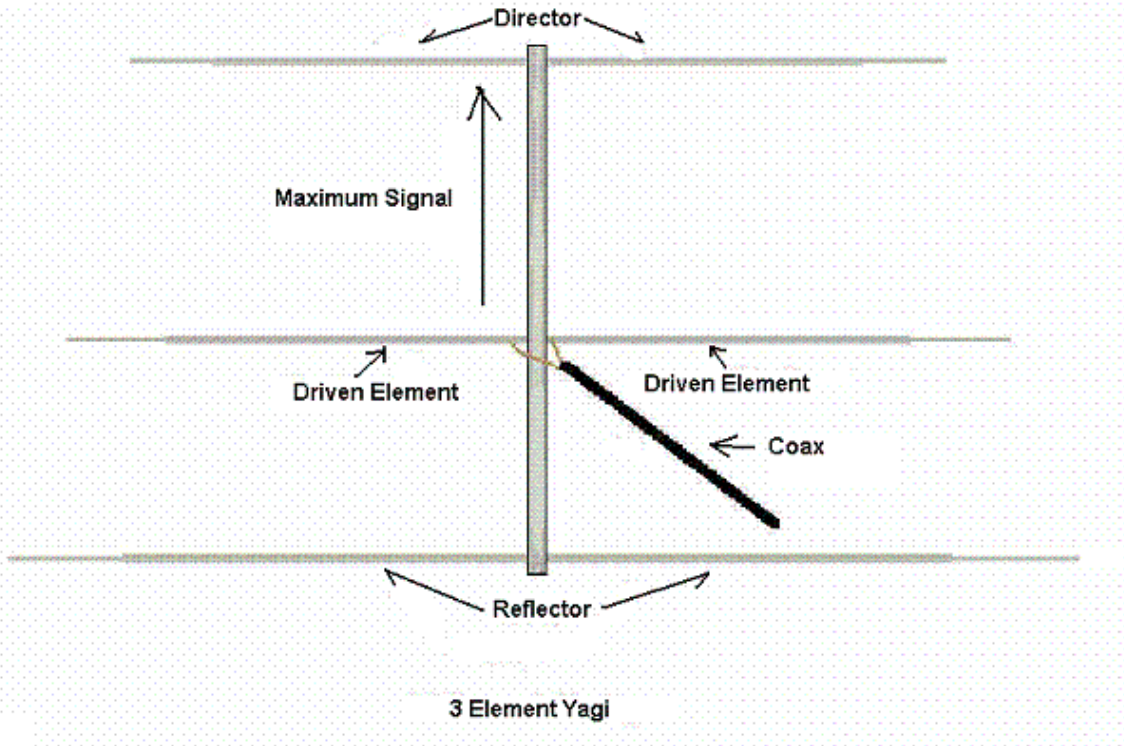
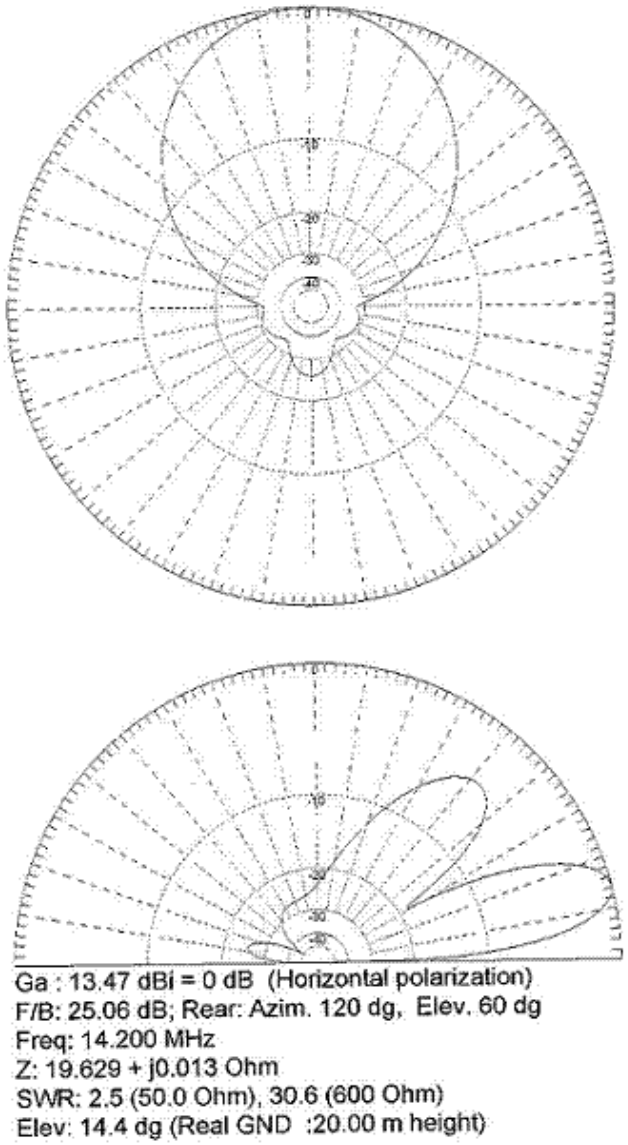


Figure 34. 3-Element Yagi Radiation Pattern



The reflector of a yagi is about 5% longer than the driven element. The reflector, being longer, will have inductive reactance. The inductive reactance shifts the phase of the re-radiated wave, which radiates and combines with the driven elements wave and reinforces it in the direction away from the reflector toward the driven element. A director is about 5% shorter than the driven element. The director, being shorter, has capacitive reactance, and this changes the phase of the reradiated wave to reinforce the wave away from the driven element opposite the reflector.

The gain of a yagi is derived from radiation being concentrated in one direction at the expense of the other directions. One hundred watts fed into a yagi with a gain of 6 dBd will have an apparent power of 400 Watts in the main lobe. Because one hundred watts put into a yagi radiates only one hundred Watts, and because that one hundred Watts of power is concentrated in the main lobe, it is equal to the power from a dipole being fed with 400 Watts. This is referred to as effective radiated power or ERP, but a yagi is not any more efficient than other antennas. Because of the Principal of Reciprocity, an antenna having a 6 dBd gain on transmitting will also have a 6 dBd gain on receiving.

Adding more directors and increasing the boom length will increase the gain of a yagi.
The front-to-back ratio ranges from 18 dB for a 2-element yagi to over 25 dB for a multi-element yagi,

provided the parasitic elements are carefully tuned. The gain of a yagi is generally proportional to the boom length and not necessarily the number of elements. Doubling the boom length, while keeping the proper number of elements for that boom length, will add about three more dB of gain.

Tuning the yagi for maximum gain makes the bandwidth very narrow, and it will have a poor front-to-back ratio. For these reasons, we dont recommend tuning a yagi for maximum gain, because you will only increase the gain by a fraction of a dB at the expense of front-to-back and feed-point impedance. Tuning the yagi for maximum front-to-back will help eliminate interference coming from the rear of the antenna. The building of any yagi involves compromise spacing and element tuning.

As you make the yagi larger by adding directors, the main radiation lobe becomes narrower increasing the gain and ERP. The gain of a yagi with four elements is about 7 to 8 dBd. You used to see 3 or 4 element yagis advertised claiming a gain of more than 10 dB, but they never said if that gain was referenced to an isotropic or a dipole. That gain also involves the gain derived from signals reflected from the ground adding to the direct wave. A more realistic gain figure is the "free space gain." Some companies, who sell monoband yagis, inflate their gain figures. Beware! Increased spacing of the elements will increase the gain of a yagi up to a point. Increasing the spacing past that point will reduce the gain. The spacing of a reflector or director needs to be in a range of 0.1 to 0.3 wavelengths. With a 3-element yagi maximum gain occurs with both parasitic elements spaced at about a quarter wavelength. Second and third directors can have wider spacing.

Most hams do not build yagis but buy them from the many companies who sell them. Ham catalogs are full of pre-cut and tuned yagis that come in boxes ready to be assembled in the back yard. Many of these are very good. However, there is a lot of satisfaction to be gained from building your own.

In 1971, we purchased, a 15-meter monobander being sold by a reputable company. Its performance was disappointing. It had only a 10-dB front-to-back ratio. That design is no longer being sold. After reading some books, we readjusted the antenna elements to some new dimensions and it performed much better. This was the beginning of our yagi building.

During the last nearly 50 years, we built many yagis. During the period of 1979 until 1986, many multi-element yagis were constructed, gain measured, formulas derived for spacing and element length, and the radiation patterns plotted on graphs. In 1986, a computer program titled "Yagi" by Dean Straw, N6BV, was bought. From that point on, that program was used to design and set the element lengths to their proper values. Not much difference in performance of the new designs was seen over what was previously used, but tuning parasitic elements and running back and forth to the field strength meter was eliminated. There are many better computer programs available today for designing yagis and other antennas.

The largest yagis we built were a 4 element 20-meter yagi on a 38-foot boom, a 5 element 15 meter one on a 27-foot boom, and a 5 element 10 meter beam on a 24-foot boom. These are modest designs compared to some of the big antennas used by contest stations. All these yagis were stacked one above the other on a 20-foot mast coming out of the top of the tower. The 20 meter one was on the bottom, next came the 15-meter, and the 10-meter yagi was on top. This method of stacking yagis for different bands one above the other makes what is called a "Christmas tree array." These antennas worked well. Since retiring and moving back home, we use pre-tuned directional antennas because of the lack of a good place for an antenna range. Climbing is not now an option because of age and infirmity.

If you make the reflector 5% longer than the driven element and the director 5% shorter than the driven element, you will be pretty much in the ballpark. The beautiful part about a yagi is it will work reasonably well with the element lengths only in the ballpark. By carefully tuning, you will get a fraction

of a dB more gain or a few more dB front-to-back, because the spacing and diameter of parasitic elements affect the length required for those elements. A yagi can be tuned for maximum forward gain, maximum front-to-back ratio, or best impedance, but you can achieve only one of these conditions at a time. Element tuning, at best, is a compromise.

Most hams who are yagi builders do not tune their antennas at all, but use published dimensions for building them. Yagi builders who do tune, tune for either gain or front-to-back and then match the driven element with a gamma match, hairpin match, a series-resonant coax matching section, or a step down balun. The feed-point of a properly tuned yagi is close to 25 ohms.

Formulas for calculating yagi element lengths will not be given in this book. Because yagi elements are made from telescoping aluminum tubing, the elements will be tapered. The diameter of the elements and the taper determine the lengths required for tuning of the elements. A tapered element will resonate higher in frequency than one not tapered. The formula to calculate the length of the tapered elements is complicated, but there are computer programs to do that.

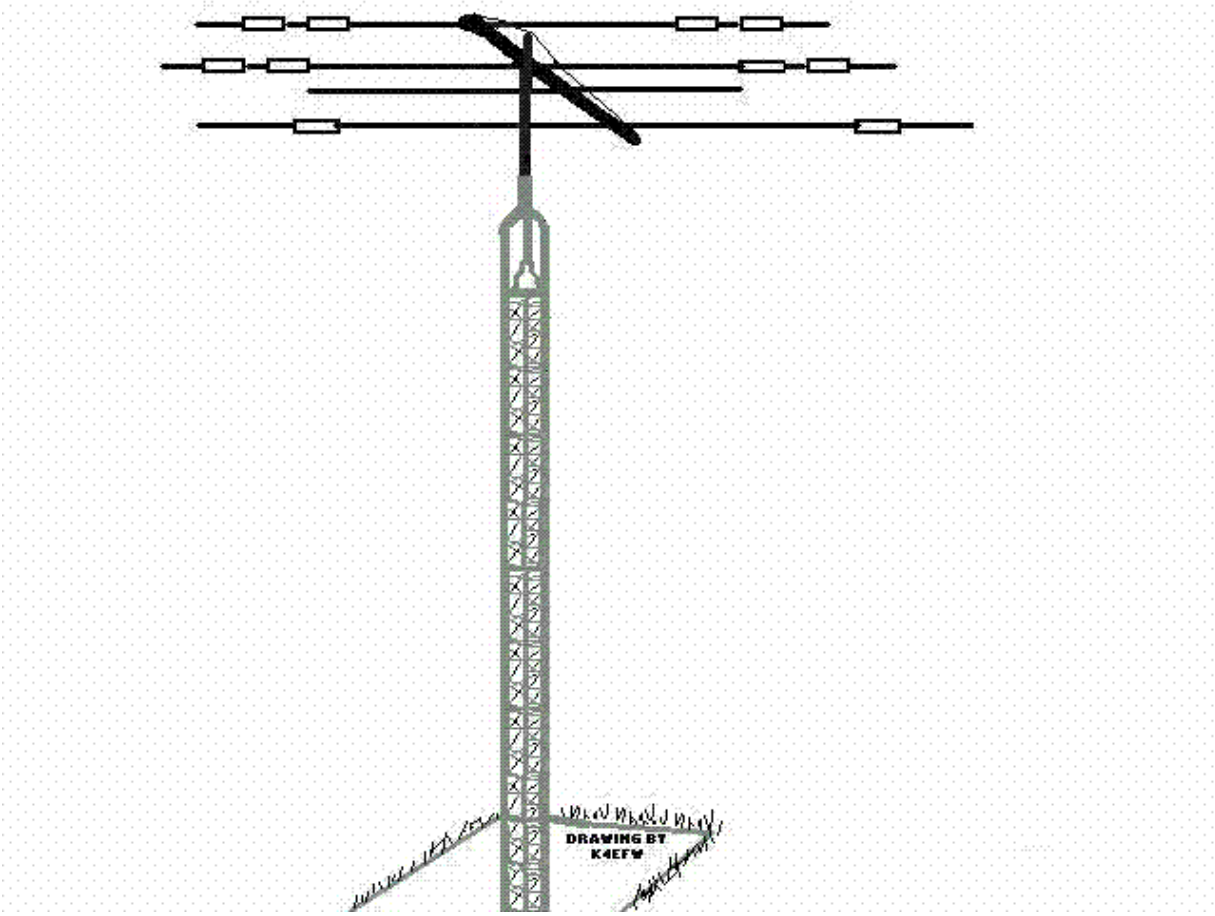
2. Trapped Multi-band Yagis

Some yagis have traps in the elements to make them into a multi-band beam. Many of these commercially made antennas are available at ham radio stores or directly from the manufacturers. In a 3-element, 3-band design, the spacing on the booms is a compromise. A 3-band beam is known as a "tribander." The spacing is close on 20 meters, optimum on 15 meters, and wide on 10 meters. You cannot tune the trapped elements for maximum performance on three bands simultaneously and have a good match on all those bands. Since a good match is important to most hams, gain and front-to-back ratio are sacrificed for a good match on triband beams

The inductors in the traps load the elements in triband beams. Therefore, the elements are shorter than the elements of a 20-meter monobander. Regardless of the compromised design, a triband-trapped beam is much better for working DX than a dipole. Many hams have achieved working over 300 entities with tribanders having short booms.

The radiation pattern from a yagi is at a lower angle than a dipole. This gives the impression a yagi has much more gain than it does. A dipole has unity gain, but that gain will be at a higher angle. The dipole puts out a weaker signal at the low angles needed to work DX, and a yagi puts a strong signal at low angles. In comparing a dipole to a yagi, the yagi may only have a 4 dBd gain in its major lobe. The gain of the yagi at a low angle may be 10 dB or so better than a dipole at that same lower angle. The gain of any antenna is always measured in its major lobe, irrespective of where the angle ar which the maximum radiation lobe occurs.

Figure 35. Trapped 3-element Yagi



The above picture shows two sets of traps in two of the elements and one set in the rear element. The front element is the director with traps for 10, 15, and 20 meters (it takes two sets of traps to make the elements work three bands). Directly behind it is the driven element with traps also for 10, 15, and 20 meters. The rear element is trapped for 15 and 20 meters (a single set of traps makes it work two bands). The entire lengths of the three longest elements are resonant on 20 meters. The short element is a reflector for 10 meters. Only the part of the antenna between the 10-meter reflector and the front director is used on 10 meters. The maximum signal is radiated in a direction coming out of the page toward you. Mosely builds trapped antennas that have two traps in one enclosure and you can not determine the bands from the traps as you can on Hy-Gain and Cushcraft beams.

Some triband beam models as the one above are built with longer booms so they would have more gain on 20 meters, a good match on all bands, and optimum 3-band performance. They achieve this by interlacing extra monoband reflectors and directors on the boom placed between the 20-meter elements as is done with the antenna in figure 34. The extra elements have no effect on 20 meters or any band for which they are not resonant. Some amateurs mistakenly think the extra elements work on all bands, but they dont. The Cushcraft A-4 shown above is not a beam with four working elements on any band. The old Hy-Gain TH6DXX and Mosley Classic 36 had six elements on the boom. They both had three trapped elements and three monoband elements. They had three working elements on 20 meters, three on 15 meters, and four elements on 10 meters. The trapped reflector worked on 15 and 20-meters. The trapped driven element worked on all three bands. The trapped director worked on 10 and 20 meters. On the boom was a resonant reflector for 10 meters and one each resonant directors for 10 and 15-meters. When using one of them, we have often heard amateurs saying they were using a six-element beam. This gave the other station the mistaken idea they were working someone with an antenna with six working elements. Other beam antennas interlace additional elements of different lengths to make the

tribander into a 5-bander covering 20, 17, 15, 12, and 10 meters. Hy-Gain makes a 5-band yagi for 20 through 10 meters that has 11 trapped and monoband elements. It is the Hy-Gain TH-11. Mosely makes a 6-bander that includes two elements for 40 meters. It is the Pro-67.

In order to achieve better SWR curves over a wide bandwidth, some triband yagis have two driven elements spaced 3 to 5 feet apart. The front driven element is shorter than the rear driven element. Both driven elements are trapped. This double driven element scheme is called a log-cell. A log cell, by itself, has a small gain and may slightly increase the overall gain of the tribander. The KLM KT-34 and the HY-Gain TH-7 are examples of this kind of antenna.

Is a monobander better than a tribander? We dont know if our tests can be duplicated and no one else has ever said he has actually compared the two antennas. It is "common knowledge" that traps have loss. Therefore, the ham fraternity believes a monobander has to be better. From the tests we performed here, we believe it is a myth a monobander is significantly better than a tribander having an equal boom-length. We believe the traps do not have enough loss to make enough difference to matter. However, monobanders having very long booms and many directors will outperform any tribander.

Having two towers, both having the same height and being 100 feet apart, made it possible for us to do the experiment described here. The result is useful information because it was made in a real world situation that would be comparable to the average hams location. Both antenna element lengths were set to Hy- Gain specifications. The constants were terrain, antenna height, antenna boom length, frequency, coax length, and power level. The only variable in the tests was the two antennas being tested. The test was performed to see how much loss antenna traps have. Had there been more than one variable, the tests would not have been valid, because in any scientific experiment, the test is valid only when one variable is being tested. In addition, more than one test has to be made in order to average out the collected data errors. In this case, many tests were made.

On one tower was a 20-meter four-element Hy-Gain 204-BA monobander with a boom-length of 26 feet. This antenna is arguably not one of the best monobanders made, but it is what we had and it was about the same size as our tribander. On the other tower was a trapped 6-element Hy-Gain TH-6 DXX tribander having a 24-foot boom. The entire tribander boom-length was used on 20 meters, so both boom-lengths were comparable.

The transmitted signal strength of the two antennas was compared on 20-meters. This test involved many DX stations and one local amateur 5 miles away. With both antennas pointing toward the receiving station, a carrier power of 10 watts was fed from the transmitter, and held constant while the antennas were "hot" switched several times. (The power level was unimportant as long as it was held constant on both antennas). None of the many DX stations involved in this test could see any difference in either antenna, and, yes, their analog meters could discern a difference of one dB. These tests by themselves were not conclusive because of the possibility of fading signals (QSB). A second series of tests was performed with a local ham when 20 meters was dead. Testing with him was done to eliminate QSB from spoiling the results. He could also measure no difference on his S-meter. He could also see a one-dB difference on his analog S-meter. As a third series of tests, the antennas were switched while we looked at the signals on the S-meter from distant stations and the local station. No differences in received signals were noted. Maybe the difference was a monobander has only a few tenths of a dB less loss, such a small amount of difference no one was able to see it on receiver S-meters. Certainly, the difference in the two antennas was less than one dB.

Conclusion: The Hy Gain TH6DXX and the 204-BA antennas perform equally well on 20 meters at a height of 56 feet.

3. The SteppIR Antenna

The latest developments in yagi designs are found in the ones being sold by SteppIR Antennas. There are two, three, and four element versions. All these versions are frequency agile and cover continuously from 13.5 to 54 MHz. The MonstIR adds three very long elements for 6.9 to 13.5 MHz. The elements are made of fiberglass tubes with beryllium-copper ribbons inside. Each element has stepping motors to wind and unwind the copper ribbons to change their lengths inside the tubes. A multi-wire control cable connecting the control box to the stepping motors accomplishes this. The proper element lengths for all frequencies in its range have been calculated by a computer and stored in the control boxs computer. As you move from frequency to frequency, the control box in the shack readjusts each element length. Thus, the antenna is configured into a properly tuned monobander for any frequency in its range. These antennas are expensive, but the hams who own them say they are worth the money.

4. The Log-Periodic Array

Another beam antenna that looks like a yagi is the log-periodic antenna. It is configured using many elements with each element being shorter than the one behind it. This means the longest element is at the rear of the array and the shortest element is at the front. All elements are divided in the center and insulated from the boom, and all elements are driven. On both sides of the insulator at the center of each element, wires run from the front element of the array to the rear element. Each wire criss-crosses the other ones but they do not touch. That makes a 180-degree phase reversal from one element to the next one behind it. The feed-point is across the insulator at the shortest element. The feed-point impedance is about 200 ohms and a 4:1 balun is used to feed it.

The advantage of the log-periodic antenna is, it that it is very broad banded and it can cover all frequencies with an SWR below 2:1in its design frequency range. The disadvantage is the gain of a log-periodic antenna is lower than a yagi with an equal boom length. There are designs being sold today that cover continuously from 14 to 30 MHz. In Fort Gordon, Georgia, there used to be a monster log-periodic at the MARS station that covered from 2 to 30 MHz. The boom length was 120 feet and the antenna was rotatable.

5. Directional Cubical Quad and Delta Loop Antennas

We built a number of quads at various times and with them on the test stand and with the bottom wire a foot or so above the ground, worked many DX stations. When we built yagis and they were on the same test stand nine feet above the ground, we could hardly get a signal out of the back yard. Since the vertical beam-width of a quad is narrower than a yagi and the radiation angle is lower, the quad will work better at low heights. Because of its lower angle radiation, many quad users claim a quad "opens and closes" the band.

The two-element cubical quad is a square-or diamond-shaped loop antenna that has a second loop acting as a parasitic element. The quad configuration has all loops in the vertically oriented plane as figure 35 demonstrates. Feeding it in one of the horizontal wires results in horizontal polarization, and feeding it in one of the vertical wires makes it vertically polarized. Every two-element quad being sold today uses a reflector for the parasitic element, although it is possible for it to have a director. The theory of operation is the same as that of a yagi.

Some quad builders believe a diamond-shaped quad has more gain than a square-shaped one. Their logic is that since the maximum current points of both wires are spaced farther apart than with a square quad, the increased spacing of the current points should produce higher gain. To find out if this was true, we built both a diamond-shaped and a square-shaped quad for two meters. Using a commercial

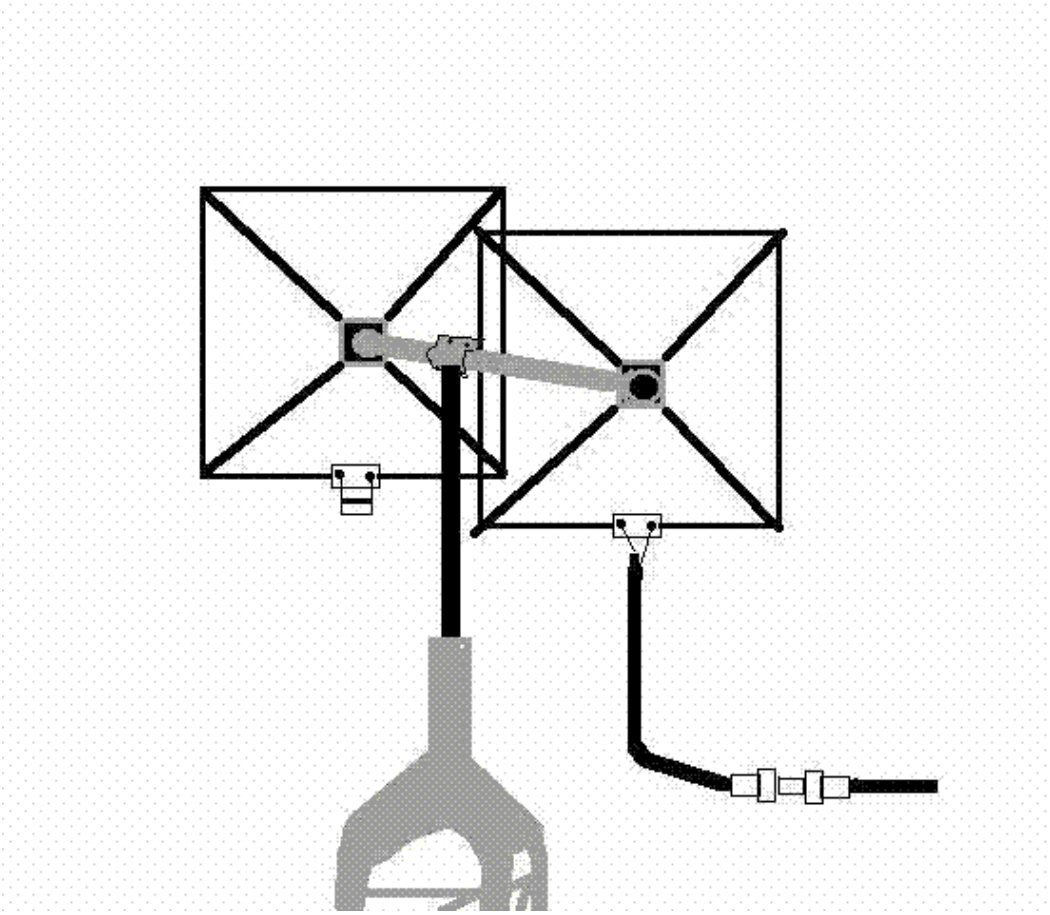
field-strength meter connected to a receiving antenna, we fed equal amounts of power to both antennas and measured the radiated field in each ones major lobe. Field strength measurements were made a few wavelengths away and many wavelengths away from the quads. No difference in the radiated field of either could be found.

According to Bill Orr in his book about cubical quads, a two-element cubical quad is equal to a pair of 2-element beams; one is stacked over the other a quarter-wavelength. The ends of the beams bottom driven element are bent up and the top element has its ends bent down where the ends of the top and bottom elements are joined together on the side. When they are joined, this forms the square we call a quad. The bottom element is then feeding the top element from its ends. The parasitic elements have the same configuration except the wire loop has the ends bonded together to form a continuous square.

There are multi-element quad designs that use one or more parasitic directors in addition to the reflector. Adding a director will lower the feed point impedance. The wire of the reflector is about 3% longer than the driven element, and each director has about 3% less wire than the driven element. Adding directors to a two-element quad makes the horizontal beam width narrower, producing more gain.

Another quad design "the delta loop" uses triangular-shaped driven elements. One or more triangular-shaped parasitic elements make the antenna complete. Theoretically, the delta loop antenna will have slightly less gain than the cubical quad, because there is less enclosed area in the triangular loop. We believe that there are no instruments available to hams to be able to measure the difference.

Figure 36A. Single Band Cubical Quad



Most cubical quad and delta loop antennas that can be rotated are used on 20 meters and higher. A few

ambitious hams have built rotatable quads for 40 meters. Others have made 80-meter quads, supported between trees, fixed in one direction.

In order to make the quad smaller, adding loading coils or linear loading sections in its wires has been suggested, but that will defeat the purpose of using a quad. Because the quads gain is produced by the enclosed area inside the loop, reducing the enclosed area will result in less gain.

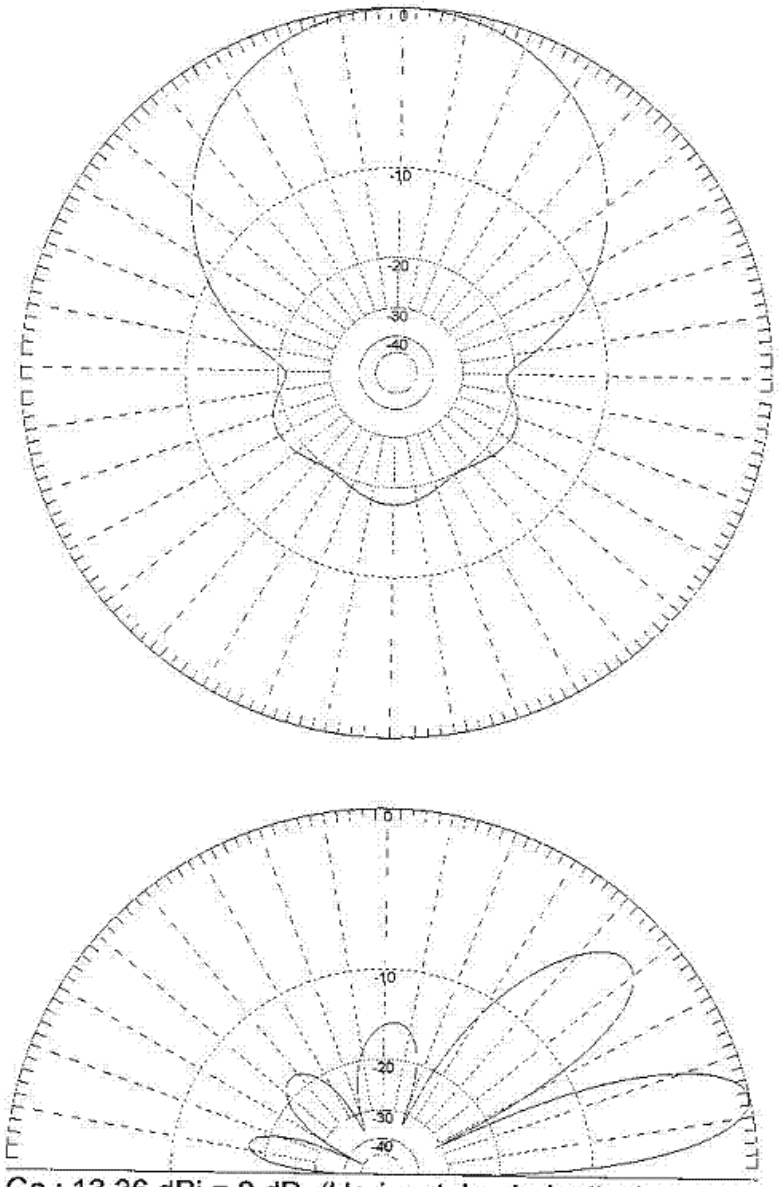
The wires for quads for 20 through 10 meters are strung around the perimeter of an "X shaped frame made of fiberglass poles or bamboo. Each element has its own X-shaped frame. A smaller X-shaped metal structure, called a "spider," attaches the poles to the boom. The poles are referred to as "spreaders." The four spreaders attached to the spider form the "X." The "X" can be rotated 45 degrees on the boom to form a diamond-shaped quad instead of a square quad. A few have tried with limited success to make the spreaders out of PVC or aluminum.

A wire is attached near the ends of the spreaders to form a loop around them. The two ends of the wire are connected to an insulator to attach the feed-line as is done on a dipole. The quad loop has a theoretical feed-point impedance of 100 ohms. To match it, you can use a quarter-wave matching section of 70-ohm coax, a gamma-match, or a 2:1 balun. More on this is in another paragraph. The delta loop is made much the same way, but it requires only three spreaders to form an equilateral triangular loop. It is matched the same way since the feed-point impedance is about the same.

The reflector and director are formed the same way as the driven element except the two ends are shorted together to form a continuous loop. In order to get maximum performance from a quad you need to tune the reflector for either maximum gain or best front-to-back ratio. For tuning purposes, the wire of the reflector is cut a little shorter than calculated and the ends of the loop are connected to an insulator. A shorted stub, consisting of two parallel wires, is connected to the loop ends and hangs down from the insulator. Another wire is shorted across the two parallel stub wires. The shorting wire is moved up and down the stub to tune the reflector. The stub is a means of adjusting the total length of the reflector. See Figure 36A. A field strength meter is needed to do this and you need a large area and two people. The field strength meter needs to be placed several wavelengths away from the antenna. Low power is fed into the antenna while it is tuned. One person tunes the reflector while the other person reads the field strength meter. Tuning the reflector involves tuning the stub for minimum signal off the back. Once the shorting wire has found its proper position, it is soldered in place. Quads made by the formulas work satisfactorily without tuning. Tuning for maximum front-to-back ratio instead of maximum gain will do more for the performance of the quad.

Figure 36. Radiation pattern of a Two Element Cubical Quad at 65 Feet

MMANA-GAL v. 1.0.0.65



Ga : 13.36 dBi = 0 dB (Horizontal polarization)
F/B: 17.62 dB; Rear: Azim. 120 dg, Elev. 60 dg
Freq: 14.150 MHz
Z: 86.586 - j2.470 Ohm
SWR: 1.7 (50.0 Ohm), 6.9 (600 Ohm)
Elev: 13.1 dg (Perfect GND :20.00 m height)

Some believe you cannot stack another antenna above a quad. They assume that because the quad has both vertical parts of the loop, a metal vertical mast will couple to the vertical part and detune the quad. We believe a vertical mast will have to be resonant at the operating frequency to detune a quad. Using MMANA, the quad was modeled with a metal vertical mast going through the plane of the quad. The only difference observed was that the resonant frequency was changed by a couple of kHz. The gain and front-to-back remained the same.

The gain of a two-element quad is nearly the same as an average 3-element yagi. The best part of the gain of a quad is the vertical beam width, or H-plane of the major lobe logically should be narrower due to it being equal to two stacked beams. For this reason, the 2-element quad has a lower angle of radiation. A horizontally polarized quad should have a slight advantage over a yagi. A lower angle is better for working DX. While operating using both quads and yagis, we have noticed that the horizontal beam width or E-plane of a quads pattern is wider than a 3-element yagi. We believe the horizontal beam-width of the quad is the same as a two-element yagi. This is why the 2-element quad is not as directional as a 3-element yagi.

Modeling our 2-element quad in free space on 20 meters, we found its gain to be 5.49 dBd. The boom-length of the quad is 8 feet. A three-element yagi with a boom-length of 16 feet will have 6.4-dBd free-space gain on 20 meters. The free-space gain of a 20-meter optimum spaced monoband yagi on a 25-foot boom will only have slightly more gain.

The compromise spacing for a 2-element multi-band quad for 20 through 10 meters is 8 feet. This spacing is 0.115 wavelength on 20 meters, 0.175 wavelengths on 15 meters, and 0.23 wavelengths on 10 meters. These spacings are within acceptable limits. For a single-band 20-meter quad, space the elements 12 feet apart. If you want to build a 12 and 17-meter dual band quad, the spacing will be 8 feet, the same as it should be for 15 meters. Eight feet is also a satisfactory spacing for a 10-meter quad, but it can be as close as four feet.

With smaller perimeter requirements, loops for the higher bands can be strung inside and parallel to the lower band loops to make a multi-band quad. It is easier to make a multi-band quad than a multi-band yagi. Quad kits for triband and 5-band quads are available. These kits cost less than a multi-band beam.

In the construction of most quads, an insulator is put in the bottom horizontal part of the wire on the driven element so it can be fed like a dipole. A 2-to-1-balun transformer will match the feed-point to 50-ohms, then you can tie all the feed-points of a multi-band quad together. The Lightning Bolt Antennas 32MCQ/WB quad feeds five loops this way and the SWR is 1.4:1 or less on all five bands. The person manufacturing the Lightning Bolt quad went out of business on December 12, 2005.

With other more complicated schemes, each quad loop is fed separately, and each loop uses a 70-ohm odd multiple of a quarter-wave series matching section placed between the 50-ohm coax and the feed-point. Used this way, the quarter-wave matching section will match 50 ohms to 100 ohms. A remote antenna switch will have to be mounted close to the feed-point to select the desired loop. Other builders use a separate gamma-match on each driven element to get a perfect match to a 50-ohm coax but this method would also require a remote antenna switch. Without the switch, several pieces of coax, one for each band, would have to be run into the shack.

If you are going to build a monoband quad, you need to use the following formulas to cut the wire loops to these approximate lengths:

For the driven element, you divide 1005 by the frequency in MHz.

For the reflector, you divide 1030 by the frequency in MHz.

For the director, you divide 968 by the frequency in MHz.

Make any additional directors the same length as the first one.

These formulas were derived experimentally from tests run here. The exact measurements will be determined by the element spacing, but the lengths cut by these formulas will be very close for any reasonable spacing.

After giving you the advantages of a quad, here are the disadvantages: The two-element quad for 20 meters is large vertically and horizontally. When the 20-meter quad is on the ground, the boom is 8 feet high and most people arent tall enough to maneuver it by holding the boom. Some quads, which are made from lightweight materials, are flimsy, and they will suffer during wind and ice storms. The best-constructed quads have their spreaders made of heavy fiberglass. Those quads, although they are heavier, stand up well under adverse weather conditions. The Lightning Bolt quad used here has stood up very well during three ice storms in the past two winters.

Here is some information we discovered after originally writing this book. The MMANA antenna-modeling program does not perform very well when modeling a quad. On 20 meters, the modeling program says the front-to-back ratio of our quad is at a maximum at 14525 kHz, but actually, it occurs at 14050 kHz. The measurements of actual front-to-back were made using a field strength meter. We reduced the power levels off the front to give the same field strength reading we got off the back. The front-to-back ratio in dB was calculated from the two power levels. What was interesting was the maximum front-to-back ratio occurs at a single discrete frequency and the front-to back deteriorates somewhat on either side of that frequency. While looking at the radiated field off the front, the field strength does not vary one dB across the whole band. Maximum gain and maximum front-to-back was very close to the same frequency. Not having tested them in this way, we believe yagi beams perform the same way regarding front-to-back ratio and gain. In working stations, the gain is the important parameter. Front to-back ratio is important in reducing interfering signals from behind the antenna. We decided to tune our quad for maximum front-to-back rather than for maximum gain. The next step is to lower the quad and carefully tune the reflector for each band. After running tests to determine the frequency where maximum front-to-back occurs, we found the maximum measured front-to-back ratio was 22 to 23 dB.

Good news! After writing the above paragraph, we lowered the multi-band quad and reduced the reflector element lengths on the two-element Lightning-Bolt Quad. The original reflector lengths were too long according to the field strength readings we made. The formulas that were originally used to cut the reflector lengths were anywhere from 1029 to 1036 divided by the frequency in MHz. We derived from field-strength measurements that the maximum front-to-back ratio occurred when the reflector length was cut by dividing 1022 by the frequency in MHz. While searching the Internet, we discovered EI7BA in Ireland used 1019 divided by the frequency on his multi-band quad. We decided to use his formula and we could lengthen the reflector by adjusting the stubs if necessary. After cutting the reflectors to the new dimensions, we made new field strength readings. The front-to-back ratio occurred near the frequency of our calculations. In addition, the frequency of maximum field strength from the front also occurred inside each band. As an example, today we were listening to GD4PTV on the Isle of Man on 17 meters. On the front of the quad, he was S7. With the quad 180 degrees from him, he was inaudible. We also found that other stations were down by at least six S-units off the back. Originally, stations off the back of the quad were down only two S-units.

Several months later it was discovered that a multi-band quad tunes differently from a single-band quad

because the interlaced elements react to detune each other. That may be the reason we found the reflectors of a multi-band quad needed to be different lengths than the 1030/frequency formula.

Here are some words of wisdom about using a field-strength meter in trying to tune a quad:

Tuning the quad reflector stubs can give you misleading data. If you look only for the minimum signal from the back of the quad, that may not be the point of best front-to-back because you may have detuned the quad so that the signal from the front may have also deteriorated.

Using a field strength meter, keep the receiving antenna as short as possible to prevent the receiving antenna from being nearly resonant. Certain receiving antenna lengths seem to be frequency sensitive, that is, as you change frequency toward the receiving antennas resonant point, the field strength meter will give a false higher reading. The only problem with using a very short receiving antenna is the meter may not have enough sensitivity to make measurements from the back of the antenna.

It will be impossible to achieve a high front-to-back ratio on certain bands on a multiband-quad because the reflector wires for adjacent bands affect the tuning by interacting with each other. When the Lightning Bolt Quad was designed, we are not certain which parameter was used in its design (gain, SWR, or front-to-back). From the field strength readings made with that design, it was impossible to draw any conclusions. If you are going to build a quad, what we said about designing a yagi is also is true for the quad: you can tune for best gain, best front-to-back, or best impedance match. You cannot tune for more than one of these parameters at a time. To tune a quad for maximum gain is relatively easy using a short antenna on the field-strength meter.

While we were trying to measure the frequency of the highest forward gain on 17 meters, we found the maximum field strength occurred at the high end of the band on one receiving antenna. Subsequently, it was strongest on the low end of the band on another receiving antenna having a different length. No changes had been made to the dimensions of the quad in either case. Trying to move the frequency of the maximum field to the middle of the band, we adjusted the length of the reflector stubs and it made no difference to the frequency where the maximum field occurred. What caused the error was we were trying to measure the field strength 100 feet in front of the quad. The long receiving antenna connected to the field strength meter was acting like a parasitic element and was not accurately measuring the signal being radiated from the quad.

6. The Quagi

A variation of the quad and the yagi is a marriage of the quad and the yagi called the quagi. The quagi has a quad driven element, quad reflector, and yagi directors. Hams who have built the quagi report the yagi directors work better than quad directors, but we have never compared the two types of directors.

At one time we converted a two-meter yagi to a quagi and compared the field strength readings from both configurations. By changing the driven element and reflector to quad loops, we measured a signal increase of 1.8 dB. We also experimented to see what effect the quad reflector had on the signal. While using the quad driven element we changed the reflector back to a yagi reflector. What was surprising to us was the configuration of the reflector had no affect on the radiated signal. Only by changing the driven element from a yagi element to a quad element made any change in the field strength. All these field strength readings were made using a commercially manufactured field strength meter. To insure our readings were valid, the power being fed to the antenna was measured and kept constant.

XVI. GAIN VERSUS FRONT-TO-BACK

As we have said before the front-to-back ratio of a multi-band cubical quad can be maximized by careful tuning to achieve about eighteen to twenty decibels front-to-back ratio. A properly designed yagi can achieve a front-to back ratio of better than thirty decibels. A two-element quad has about the same gain as a three-element yagi. You can tune a yagi or quad to either maximum front-to-back or maximum gain. You can also tune them to compromise settings somewhere in between. The question arises as to which maximum should either antenna be tuned? It is our opinion that either antenna should be tuned for maximum front-to-back ratio. In that case the maximum gain will be deteriorated by only a fraction of a decibel Let us explain why we reached that conclusion with an example.

Today we were on 17 meters to work VP8TD on Pitcairn Island in the South Pacific Ocean. He is a visitor to the island and will be there for about two more months as of this writing. A resident of the island, VP6TC, Tom Christian hasnt been heard from in months. I suspect he is getting elderly and doesnt get on much anymore. Anyway VP6TD had an enormous pileup going. We were using a three-element SteppIR yagi up sixty-five feet on our tower. Also, the amplifier puts out about 1490 watts on 17 meters. We make up for a lack of antenna forward gain with the amplifier. We worked him with one call through the pileup. The SteppIR replaced the two-element Lightning Bolt Quad about 10 months ago. When VP6TD answered us I could hear him over the pileup. From the rear of the antenna were several very loud Italian hams calling him, one of which continued to call even when VP6TD answered someone. The Italians were 180 degrees from the front of our antenna, or directly off the back of where we were beaming. Because of the superior front-to-back of the yagi, I could hear the Pitcairn Island station over the Italians. Had we been using the quad, the Italians would have been at least 10 dB louder and we could have found it impossible to make the contact.

Today, we were in contact with N4XPZ, Joe, on 75 meters while several more hams were talking about the VP6TD on 17 meters last evening. Joe said he tried to work the VP6TD station using a single wire antenna. He complained he could not copy the VP6 because of the Italians who continued to call even when the VP6 answered someone. That illustrated the point we are making in this section. The old adage is true: "You cant work em if you cant hear em!"

XVII. FEED-LINES COMMONLY CALLED TRANSMISSION LINES

Always use the best feed-line you can afford. Resist the urge to be penny wise and pound-foolish. This is particularly true of coax. Better (less lossy) coax will cost more. This cable is carrying your precious RF signal to and from your antenna.

The most common feed lines used by amateurs are 50-ohm coaxial cables. There are many types of 50-ohm coax such as RG-174, RG-58, RG8-X, RG-8, RG-213, RG-8 foam, and 9913. In this book we will only discuss these types. A suffix letter such as an "A or "U" may be attached to the "RG" numbers such as RG-8U or RG-58A. All these cables have a center conductor surrounded by a plastic insulating material, called the dielectric, and a copper braided shield covering it. There is a plastic covering on the outside of the shield to protect the conductors from water. The center conductor and the shield carry RF currents.

These are the common 50-ohm cables:

RG-174 has a very small diameter, 0.101 inches. This cable is used to carry small amounts of RF between circuits in equipment. RG-174 has the highest loss and the least power handling capability of any coax. It is useless as an antenna feed-line because of its loss and low power handling ability.

RG-58 is larger coax having a diameter of 0.195 inches. It can handle low power and can be used on the lower bands to feed antennas a one hundred feet or so away. It is not recommended to use RG-58 on 10 meters because it has a loss of 3dB per hundred feet on that band and half your power will be lost in the coax.

The next larger cable is RG-8X, sometimes referred to as mini-8. Its diameter is 0.242 inches. The dielectric surrounding the center conductor is foam rather than the solid dielectric used in the most coax. Making cables with foam insulation can reduce the loss. Some hams are successfully feeding a kilowatt of power into RG8-X on the lower bands. You will lose 2 dB of power by using one hundred feet of RG-8X on 10 meters. On 80-meters the loss of this cable is negligible.

You will want to use RG-8 or RG-213 if you are planning to use a kilowatt or more of power from 160 to 10 meters or for short runs on VHF and UHF. RG-213 is RG-8 made to military standards. Both have diameters of 0.405 inches. This cable has lower loss and can handle higher power because it has larger conductors and a larger diameter dielectric. RG-8 can handle 4000 watts peak envelope power on the broadcast band. RG-8 has only about 1dB loss on 10 meters per 100 feet. The loss becomes greater and the power handling rating of any coax decreases as the frequency of RF is increased.

There is a lower-loss version of RG-8. It is called RG-8 foam. Beldens number for this product is 8214. Because of the dielectric being foam, a larger center conductor has to be used to keep the impedance 50 ohms. The loss resistance of the larger conductor is less than the smaller conductor used in regular RG-8. In addition, the foam having many air pockets has less dielectric losses. Other manufacturers also make RG-8 foam. One hundred feet of RG-8 foam has a loss of 0.9 dB on 10 meters. Many amateurs will not use RG-8 foam because they mistakenly believe the foam will soak up water. Cut off a piece of this foam material and put it into a container of water. It will continue to float *ad infinitum*, because it doesnt soak up water. Most of the water seen in coax gets between the dielectric and the plastic outer covering and within the braid shield. Water has also gotten into the strands of the center conductor. Water will get into any coax if the ends are not properly sealed.

Solid conductors have less loss at radio frequencies compared to stranded conductors. Braid has more loss than a solid conductor used for the coax shield. A much lower loss coax, especially for higher frequencies, is available. The Belden 9913 is this product. This coax has a solid center conductor and the shield consists of a coating of aluminum foil covered with braid. The aluminum foil is a solid conductor. The braid over the foil is used to make a good solder connection because you cant solder aluminum. The mostly air dielectric material used in this product requires the center conductor to be larger to make the impedance 50 ohms. Air dielectric also has less dielectric loss than solid. There are a few manufacturers making 9913 look-alike products. One hundred feet of 9913 will have a loss of about 0.66 dB on 10 meters. There is a coax that looks like 9913 but has a stranded center conductor to make it flexible. It has a little more loss. If you are going to use 9913 on an antenna that rotates, flexing the cable as the antenna turns will cause the center conductor to break. Run the 9913 to the top of the mast, and using a barrel connector, connect the 9913 to a short run of RG-8. Run the RG-8 across the rotor to the antenna.

Coax cables of other impedances are available such as 70-ohm cable. RG-59 and RG-11 are common 70 ohm cable. Hams, except to make quarter wave matching sections, do not use these cables much anymore. There are many other types of cable other than the ones described here.

Open wire feeders, ladder-line, or window-line have much lower loss than coax. The three types are essentially the same except for the method of insulating the two wires from each other. When making open wire feed-line, you should use solid conductors, as large a conductor as possible, and as little dielectric as possible. These factors make open wire have less loss. There is so-called ladder-line for sale, which is really window line, which is made with 16 gauge solid conductors. The solid conductors make

for low loss. There is another grade of the same feed-line that has 14 gauge-stranded conductors.

XVIII. ANTENNA SAFETY

1. Erecting Antennas on Masts

Erecting antennas pose some danger especially if they encounter power lines. Never erect an antenna near a power line. Make sure to leave enough clearance so if the antenna supporting structures fall they will clear the power lines. There are many cases of metal masts being raised accidentally encountering power lines, electrocuting the person or persons raising the masts. To raise a mast can expose you to a large force called leverage, which appears to increase the weight of the mast. Exerting oneself to raise a heavy mast can result in painful muscle and back injuries. Never try to raise a mast without sufficient help.

2. Tower Safety

A tower is a wonderful device for supporting wire and beam antennas, but a person who has never put up one should seek advice of people who have experience in erecting towers. The obvious danger is falling off the tower. It should never be climbed without a climbing belt. Most people falling off a tower do so because of some kind of equipment failure or the tower collapses because of overload.

In erecting a tower, a gin pole strong enough to support the weight of the tower section being raised should be used. Do not use improvised gin poles, as the strength of them may not support the weight of the tower section and the force from the other end of the rope being pulled by the ground crew. To hold a 50-pound tower section stationary requires a hundred pounds of force, which is the weight of the tower section and 50 pounds of force of the ground crew. The ground crew must exert more than 50 pounds of force to cause the section to be raised. There would be no greater tragedy than the gin pole breaking dropping the tower section on the ground crew. Then there is the possibility of the person on the tower being knocked loose by the falling, broken gin pole.

Another problem can arise if under-sized guy cables and clamps are used to support the tower. We have seen tower failure when guy cables broke in a windstorm, or an insufficient number of clamps holding the guy cable allowed the cable to pull through the clamps. Professional tower people do not use cable clamps. They use "preformed tie-wraps" that grip the guy cables tighter as the force in the guy cables increases. Preformed tie-wraps are available from Texas Towers. Never tie the ground end of a guy cable to a tree. A tree swaying in a heavy windstorm can put enough force on the cable to cause it to break or to pull the tower over. Screw-in anchors available from mobile home suppliers make adequate anchors. Do not anchor a guy cable where a tree can fall across the guy cable. This could break the guy cable and cause the tower to fall. Never place a tower near a house, where if it falls, it could hit the house. Remember Safety First!

TABLE 1

Quarter Wave Matching Sections of 70-ohm Coax

These lengths are for coax having a solid dielectric with a velocity factor of 0.66 and foam dielectric with a velocity factor of 0.78. , You can use odd multiples like 3, 5, 7, etc. of the lengths below if those lengths are too short for your installation

Solid dielectric cable	Foam dielectric cable

160 meters 85ft 6in 106ft 4in

80 Meters 43ft 4in 51ft 9 in

40 Meters 22ft 6in 27ft 6 in

30 Meters 16ft 0in 19ft 6 in

20 Meters 11ft 5in 13ft 10 in

17 Meters 8ft 11 in 10ft 9 in

15 Meters 7ft 7 in 8ft 4 in

12 Meters 6ft 6in 8 ft 0in

10 Meters 5ft 8 3/8 in 6ft 11 in

Questions? Email Jim Abercrombie n4ja@prtcnet.com

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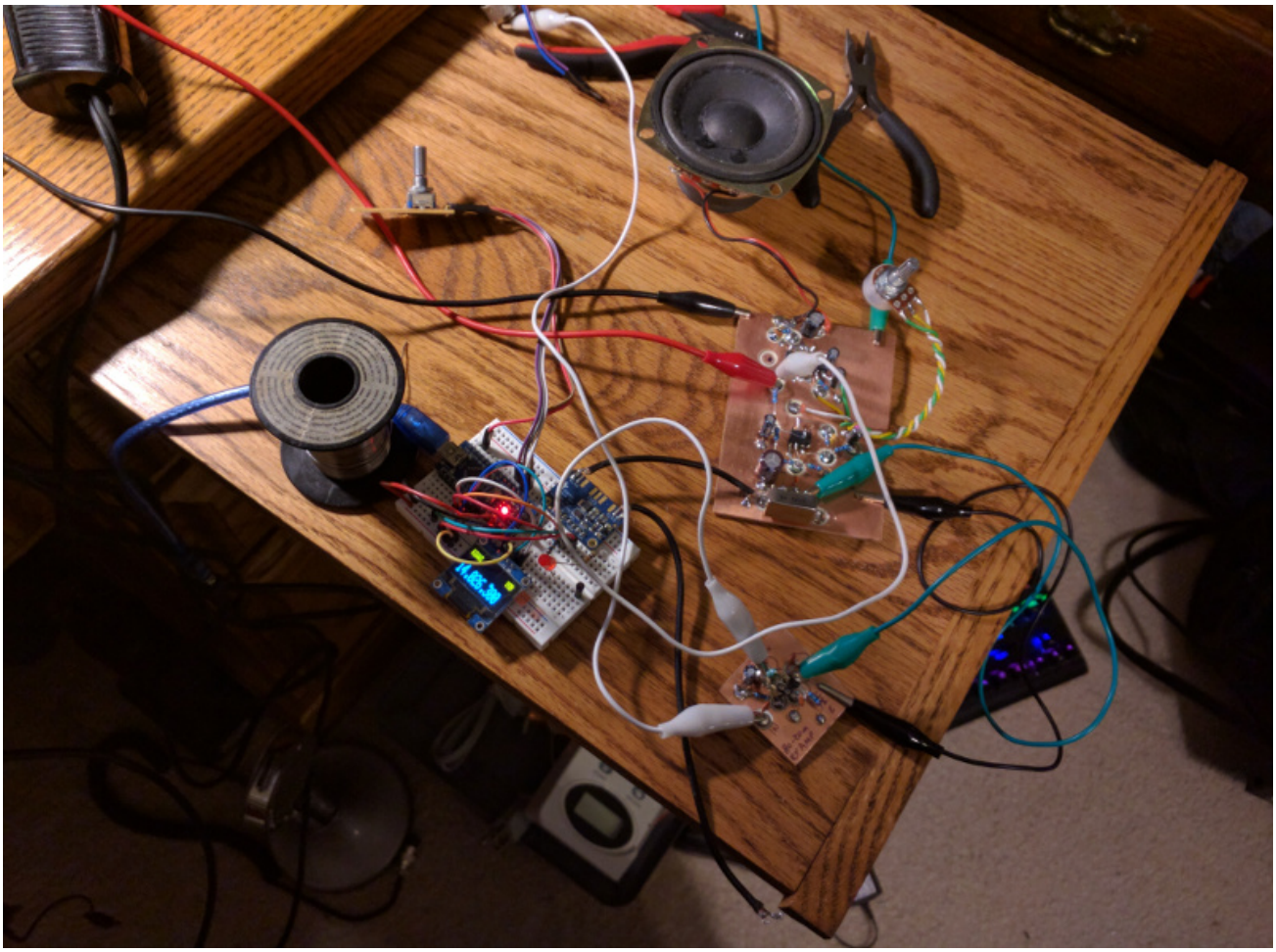
stuff that i do and things that i make

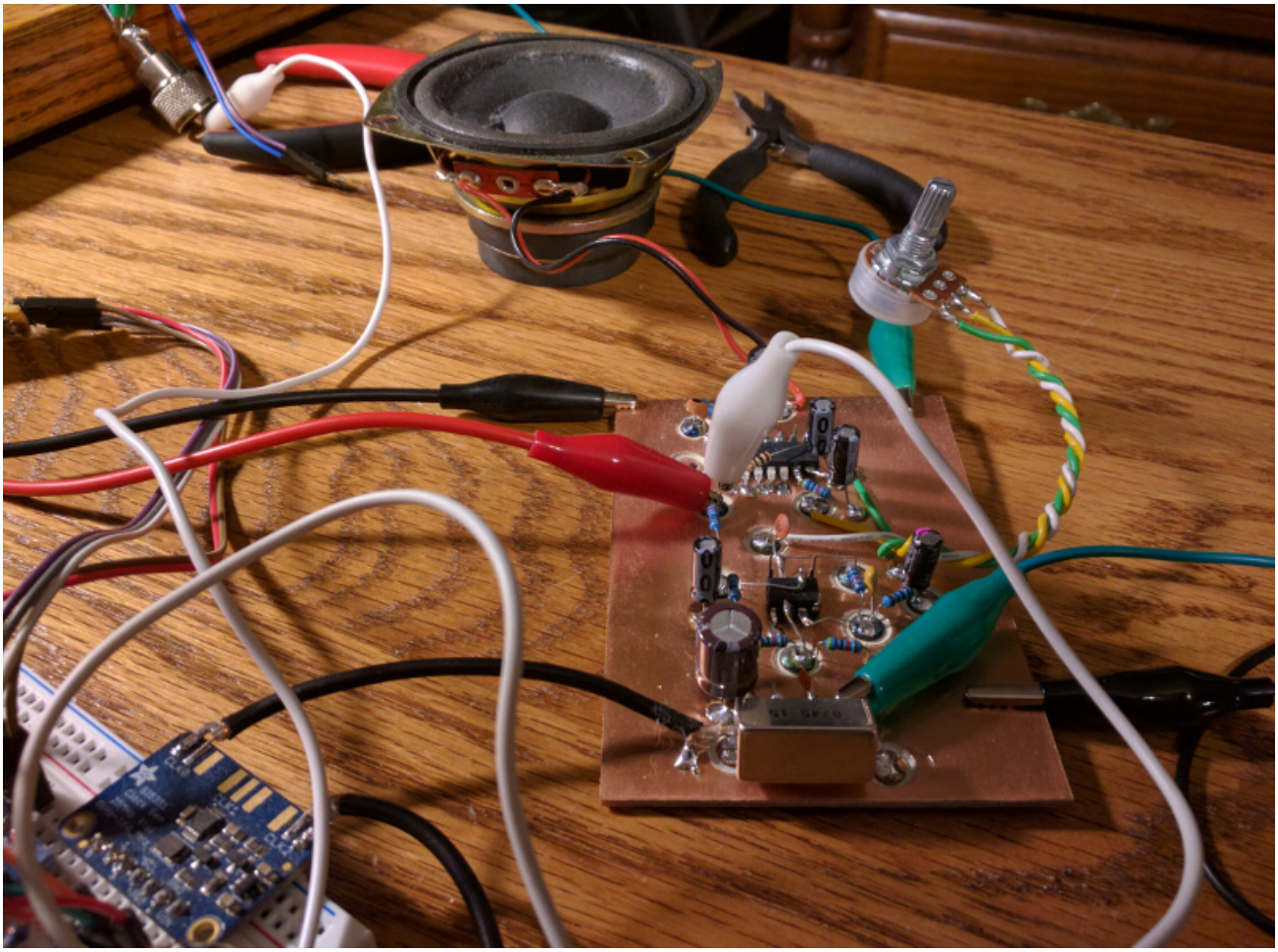
direct conversion receiver

PUBLISHED SEPTEMBER 12, 2017

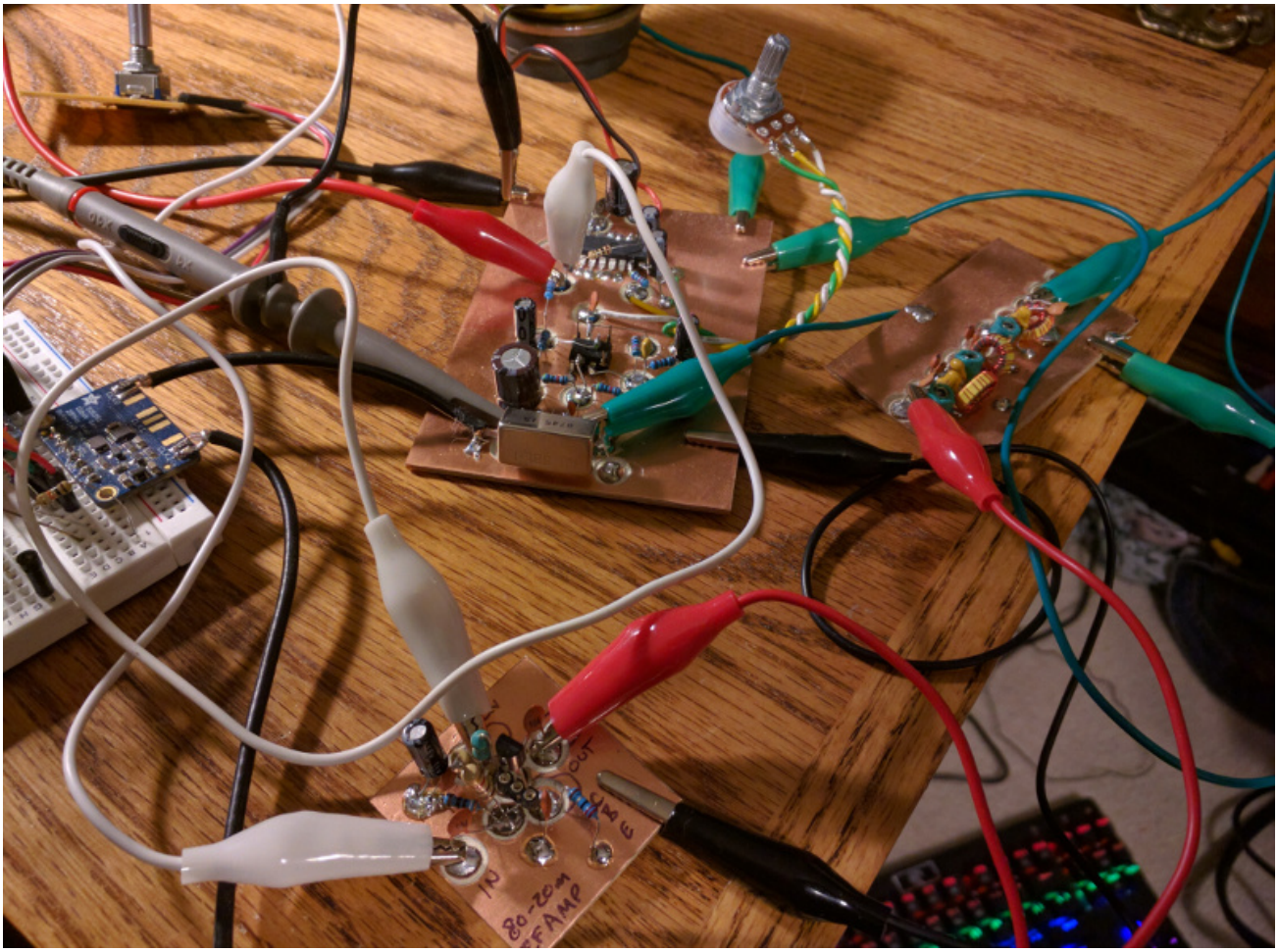
So, while I was stuck at home sheltering from the winds of hurricane Irma, I knocked together a direct conversion receiver.

I started with the audio amp that I built a while back. I added an SBL-1 mixer and an arduino/si5351 vfo. I then connected the RF amp from the previous post.





I connected it to my 20 meter attic dipole and it received okay, but was pretty noisy. Probably because of all the alligator leads and bad connections. I added a 20 meter band pass filter which helped some. I'll probably re-engineer it a bit and turn it into a superhet.



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Enhanced RF to DC converter with LC resonant circuit

L J Gabrillo, M G Galesand J A Hora[1]

Microelectronics – Power IC Laboratory, College of Engineering, MSU-Iligan Institute of Technology, Iligan City, Philippines

Email: jefferson.hora@g.msuiit.edu.ph

Abstract. Presented in this paper is an experimental comparison of the conventional and proposed design circuit of a radio frequency (RF) energy harvesting. RF to DC energy harvester simply consists of antenna and rectifier block for receiving electromagnetic radiation signal and to produce a DC voltage, respectively. In addition to this conventional circuit, the proposed design includes LC tank circuit as receiving block of a well-designed antenna radio frequency receiver. Proper choice of an antenna type, realizing of point contact Germanium diodes as rectifier and correct design values for the LC passive components, greatly improved the measurement of the maximum output power, giving approximately a 100% increase compared to the conventional method. Experimental results of the enhanced RF to DC converter measured a maximum output power of 1.80 mW at a distance of 77.84 meters from a TV signal tower operating at 165 MHz. Thus, the harvested signal was enough to supply a low power wireless device applications without battery maintenance.

1. Introduction

Developing efficient methods for extracting DC power from RF signals has become an important necessity for a number of applications involving self-powered devices and sensor nodes [1]. In recent years, development of technology is rapidly growing allowing the decrease of certain characteristics of a system or device like size and power consumption. However, these devices are powered by bulky batteries that need to be recharge or replace every so often.

Extracting energy from the environment particularly RF signal is not only an eco-friendly way of generating free energy but can be a solution to minimize the consumption and usage of battery in most wireless devices. Wireless power transfer will be possible for low-power applications only since the expected received power will be low at about 1mW.

However, converting RF energy from RF signals at different frequencies is relatively difficult issue particularly when RF signals have relatively low power levels [1,2]. The operating range of such self-powered devices has been severely limited by the failure of existing power extraction techniques to successfully extract power from radio frequency signals having relatively low power levels. This is mainly because of the problems of extracting DC power from electromagnetic radiation which consist of two main parts: collecting the incident radiated power, and converting the collected power to DC signals enough to power self-powered devices[3].

[1] To whom any correspondence should be addressed.

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Thus, proper choice and design of antenna and a rectifying circuit is needed to solve this problem. Having an efficient antenna for matching the desired frequency and a high performance rectifying circuit will greatly affect and improve the output power generated [3].

With the challenging issue of improving the generated output power generated in a conventional RF to DC converter, this paper explored the addition of properly designed tank or tuner circuit to improve input matching of the desired radio frequency received before rectification process. Also, different antenna type will be tested to determine the maximum output power generated of the overall system.

2. Design architecture

This section shows the comparison of the blocks present in the conventional and the proposed radio frequency energy scavenging method.

2.1.Conventional design block

The block diagram of the conventional RF to DC converter is shown in figure 1. In consists of an antenna, input matching circuit, rectifier, output matching circuit and a load [4].A method for performing a power extraction includes receiving an electromagnetic radiation signal using antenna, rectifying the signal produce DC voltage and providing the DC voltage to a circuit.

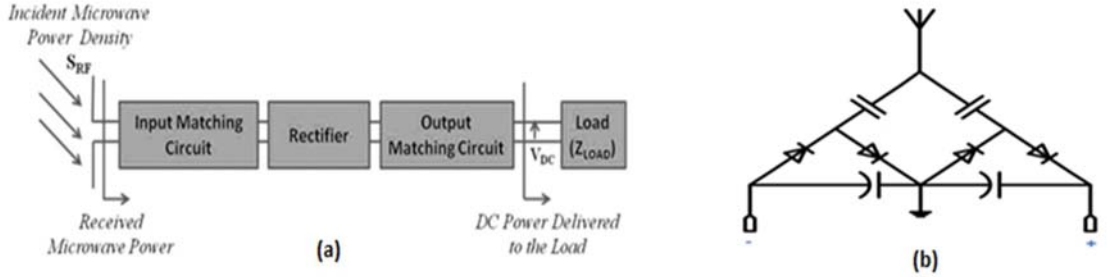


Figure 1. Conventional RF to DC Converter Block: (a) block diagram, (b) circuit.

2.2. Proposedcircuit design

The electromagnetic radiation captured by the antenna will be optimized if a proposed tuner circuit in addition to the traditional method is employed. This tuner or tank circuit converts the selected carrier frequency and its associated bandwidth into a fixed frequency that is suitable for further processing and in consideration to the required impedance matching network for optimizing the performance of the overall RF energy extraction circuit. Shown in figure 2 the block diagram and circuit of the proposed design.

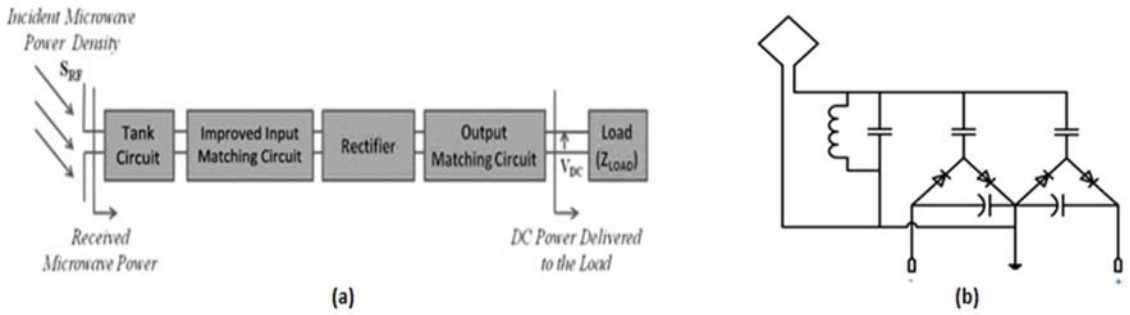


Figure 2. ProposedRF to DC Converter Block: (a) block diagram, (b) circuit.

3. Block components design

The proper choice of antenna and diode type has been greatly considered in this paper. Two types of antenna were considered as experimental comparison to the chosen loop antenna used in the proposed design of RF energy harvesting. Also, germanium diode was primarily chosen over silicon type diode due to the threshold voltage consideration. The following section will discuss the details of the components employed in this paper.

3.1. RF antenna

The proposed RF to DC energy harvester circuit used a loop antenna tuned at 165MHz television station. Loop antennas take many different forms such as a rectangle, square, triangle, ellipse, circle, and many other configurations. Because of the simplicity in analysis and construction, the circular loop is the most popular and has received the widest attention [5]and which was also employed in this paper.

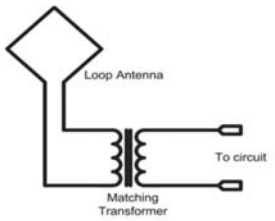


Figure 3. RF loop antenna component.

The geometrical construction of the loop antenna to tune at the required 165 MHz frequency of the transmitter has been designedwith the graph of the axial directivity, $ka = c/\lambda$ and the radiated electric fields formula:

$$E_r = E_\theta = 0 \tag{1}$$

$$E_\phi = \eta \frac{(ka)^2 I_0 \sin\theta}{4r}[1 + \frac{1}{jkr}]e^{-jkr} \tag{2}$$

3.2. Tank or tuner circuit

A tuner is a subsystem that receives radio frequency (RF) transmissions like radio broadcasts and converts the selected carrier frequency into a fixed frequency, and that is, 165 MHz in this paper. The proposed circuit employed a simple tank circuit consisting of a capacitor and inductor connected in parallel. This creates a resonant circuit which corresponds to an alternating current at one frequency. The calculated values of the capacitor and inductor in resonant to the frequency drawn by the known transmitter TV station was based on the equivalent frequency and the cylindrical air-core type inductor formula, shown in equation (3) and (4), respectively.

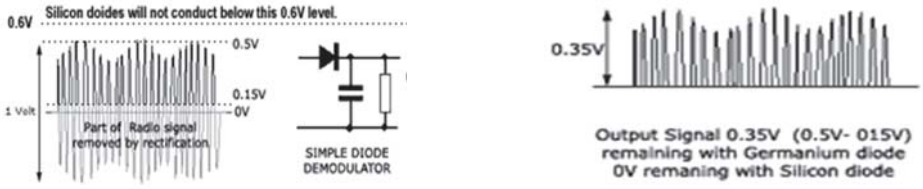
$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}} \tag{3}$$

$$L = \frac{N^2 \mu A}{l} \tag{4}$$

3.3. Germanium and silicon diode for rectifier block

Even when the forward voltage is just below 0.7V for Silicon or 0.3V for Germanium, diodes will start to conduct minute currents. For Germanium diodes, it will conduct at a forward voltage of only about 0.15V, however, a silicon diode will not start to conduct until a forward voltage of 0.6V is reached [6].

Thus, primarily due to low threshold voltage of the Germanium diodes and sometimes known as signal diodes, this type of diode is well suited for RF signal harvesting. As shown if figure 4, an example of demodulator circuit that recovers the audio signal from the amplitude modulation (AM) radio waves can utilized either Silicon and Germanium diode as a rectifier to remove unwanted half of the AM signal, having the difference of the frequency of operation and voltage used.



(a) (b)

Figure 4. (a) Test response of Si, (b) Test response of Ge.

3.4. Capacitor filter and voltage multiplier

A design of value of capacitor is very important after the rectification of the signal and which is essential on both input and output matching blocks. This capacitor filter networks will smoothen the DC rectified signal into ripple voltages of the proposed RF to DC energy harvester circuit, not to mentioned it main importance in the output of power supplies, in the resonant circuits that tune radios to particular frequencies, in electric power transmission systems for stabilizing voltage and power flow, and for many other purposes [7].

On the other hand, a voltage multiplier was also employed in the proposed design to boost up the voltage generated from a few volts to acceptable several volts as it was generally used in a high-energy physics experiments and lightning safety testing. This paper utilized a half-wave series multiplier consisting network of capacitors and diodes.

4. Experimental results

A fixed design of the rectifier circuit using germanium diode and well calculated capacitor values for the matching output were fixed in the test set-up. Correspondingly, three types of antenna, namely: straight, yagi-uda and loop antenna were designed and tuned accordingly to receive radio frequency signal from a TV station operating at 165 MHz. Also, the voltage and current measurement of the conventional RF to DC converter were considered with the three test locations, with an approximate distance of 77, 246 and 411 meters away from the transmitter TV station. The used of google earth application approximated this distance from one point to another as shown in figure 5.



Figure 5. Example of approximated transmitter & receiver distance measurement.

From the test measurement of the different types of antenna employed and at a different distance location from the transmitter TV station, it was proven that loop type antenna in an adjacent position

or placement showed a superior measurement of voltage and current which can able to power one single LED load. Accordingly, antenna position or placement for the three types was considered. Test and measurement were made for the vertical or horizontal position Straight antenna; facing or parallel position Yagi-uda antenna; and facing, parallel and adjacent placement Loop antenna. The loop type antenna measured 4.93V at no load condition at approximately 77.84 meters away from the transmitter TV station. The maximum voltage was measured with respect to the different test location as shown in figure 6.

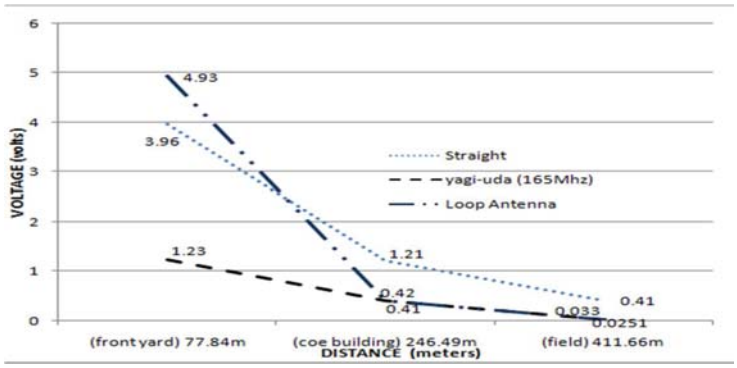


Figure 6. Maximum voltage measured of the three types of antenna.

Correspondingly, at no load condition, the maximum output power was calculated using the measured voltage & current of the three types of antenna that were designed for the conventional RF to DC converter circuit. The Loop, Yagi-uda, and Straight type antenna had measured a maximum output power of 0.887 mW, 685 mW, and 87.3 mW, respectively. The said measurement was tested at the approximate distance of 77 meters away from the transmitter signal as shown in figure 7.

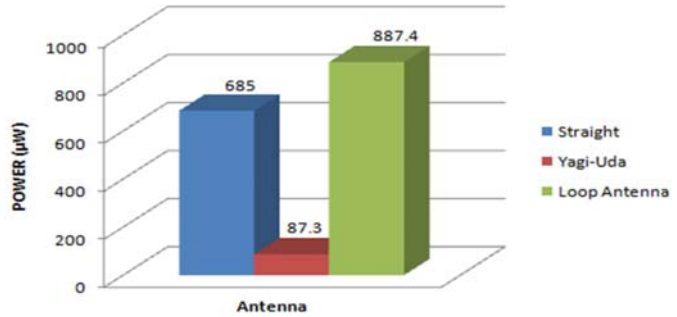


Figure 7. Maximum output power measured for the three types of antenna at 77m distance.

Considering the utilization of loop antenna, rectifier germanium diode and approximated distance of 77 meters, the conventional circuit set-up has been modified with the addition of a properly designed values LC tuner circuit. Typical and maximum measurement of the voltage and current had been recorded as shown in figure 8. Consequently, the proposed design showed a maximum output power of 1.8 mW while the conventional circuit only had 0.887 mW, that is, approximately a 100% improvement as summarized in figure 9. Also, in figure 10 shows the hardware set-up of the proposed RF to DC energy harvester.

CONVENTIONAL	Resolution		PROPOSED	Resolution	
Voltage (V)	4.86	4.93	Voltage (V)	8.50	8.64
Current (μA)	173	180	Current (μA)	202	210
Power (μW)	840.8	887.4	Power (μW)	1717	1814

Figure 8. Measured voltage and current of the proposed and conventional RF to DC converter energy harvester circuit.

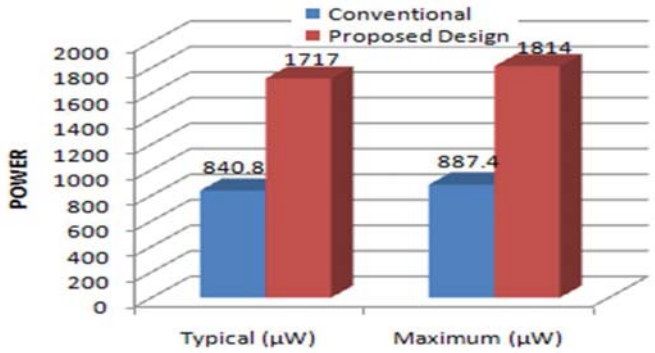


Figure 9. Output power comparison of the proposed and conventional design.



Figure 10. Actual hardware set-up of the proposed RF-DC energy harvest.

This proposed RF to DC converter circuit design with the use of loop antenna, cascaded half-wave doubler as rectifier circuit and the addition of tuner circuit was compared to other researches on radio frequency energy harvesting. Table 1 shows this comparison and the proposed design had an extreme higher power consumption at no load condition.

Table 1. Performance Comparison.

Parameters	Reference [23]	Reference [24]	This design
Voltage (V)	2.4	not mentioned	8.64
Current (μA)	51	not mentioned	210
Power (μW)	122.4	1	1814
distance from source (m)	50	40	77

5. Conclusion

The addition of a properly design values of LC tuner circuit with rectifier circuit consisting of two cascaded half-wave doubler demonstrated the highest power harvested from RF energy. Also, the use of a loop antenna contributes more in capturing ambient RF energy. The system has proved to be an RF recycler that could be very useful in indoor applications like wireless sensors.

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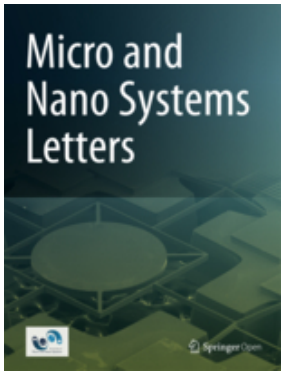
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Review
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RF power harvesting: a review on designing methodologies and applications

- Le-Giang Tran[1],
- Hyouk-Kyu Cha[2] and
- Woo-Tae Park[1, 3]Email authorView ORCID ID profile

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Abstract

Wireless power transmission was conceptualized nearly a century ago. Certain achievements made to date have made power harvesting a reality, capable of providing alternative sources of energy. This review provides a summ ary of radio frequency (RF) power harvesting technologies in order to serve as a guide for the design of RF energy harvesting units. Since energy harvesting circuits are designed to operate with relatively small voltages and currents, they rely on state-of-the-art electrical technology for obtaining high efficiency. Thus, comprehensive analysis and discussions of various designs and their tradeoffs are included. Finally, recent applications of RF power harvesting are outlined.

Keywords

Wireless power harvestingRadio frequencyImpedance matching networkVoltage multiplierAntennaWireless sensor networks

Background

Motivation for wireless energy harvesting

An early definition of a wireless power transmission system portrays a unit that emits electrical power from one place and captures it at another place in the Earth's atmosphere without the use of wires or any other supporting medium [1]. The history of RF power scavenging in free space originated in the late 1950s with a microwave-powered helicopter system [2]. Later, the concept of power harvesting or energy scavenging was explained as a technique for reaping energy from the external environment using different methods including thermoelectric conversion, vibrational excitation, solar energy conversion, and pressure gradients. This technique promises tremendous scope for the replacement of small batteries in low power electrical devices and systems. Figure 1 introduces the structure of an RF energy harvesting system and factors that contribute to the performance of the whole system.

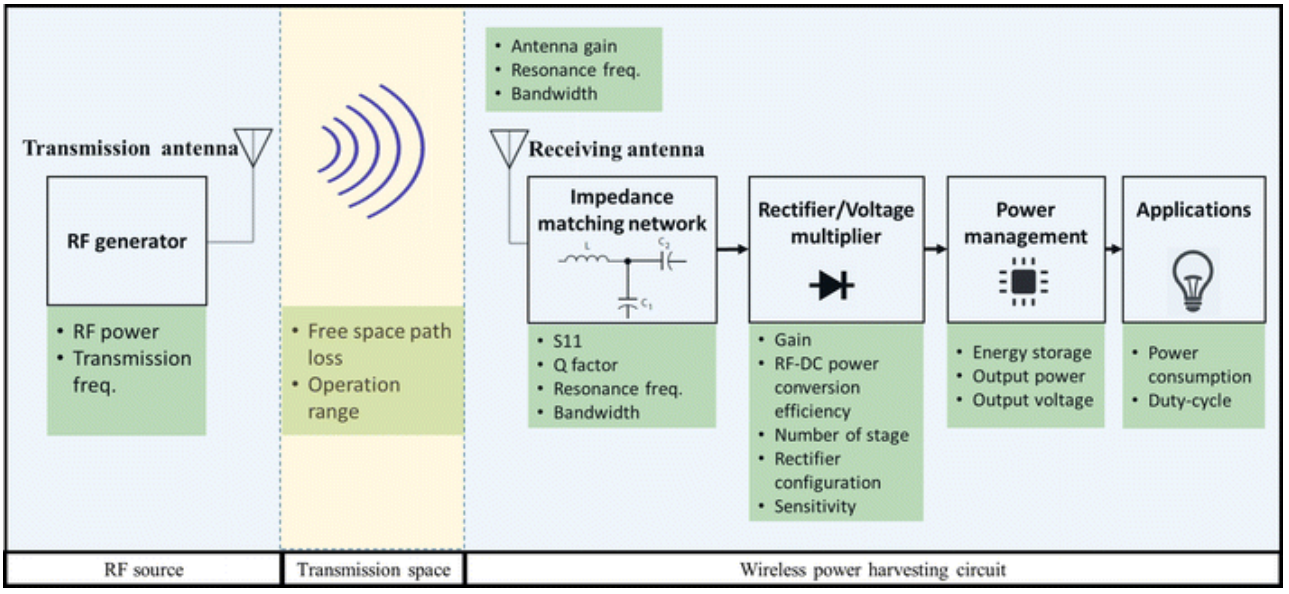


Fig. 1

Conceptual block diagram of an RF power harvesting system

RF wireless power harvesting (WPH) holds vast potential for replacing batteries or increasing their lifespans. Currently, batteries power a majority of low-power remote sensor devices and embedded equipment. In fact, batteries have finite lifespans and require periodic replacements. By applying power harvesting technologies, devices and equipment can become self-sustaining with respect to the energy required for operation, thereby obtaining an unlimited operating lifespan. Thus, the demand for power maintenance will become negligible.

The sources for WPH are available in many forms, such as solar power [3, 4, 5], wind energy [6, 7, 8], thermal energy [9, 10, 11], electromagnetic energy [12, 13, 14], kinetic energy [15, 16, 17], etc. Among them, electromagnetic energy is abundant in space and can be retrieved without limit. Electromagnetic waves come from a variety of sources such as satellite stations, wireless internet, radio stations, and digital multimedia broadcasting. A radio frequency power harvesting system can capture

and convert electromagnetic energy into a usable direct current (DC) voltage. The key units of an RF power harvesting system are the antenna and rectifier circuit that allows the RF power or alternating current (AC) to be converted into DC energy.

The processing of battery wastes is a critical problem. A majority of batteries end up in landfills, leading to the pollution of the land and water underneath. The most effective solution for reducing battery wastes is to avoid using them. Applying WPH technology will help to reduce the dependency on batteries, which will ultimately have a positive impact on the environment. Moreover, the process of harnessing electromagnetic energy will not generate wastes as it is a clean energy source.

A summary of the present sources of energy available for power harvesting is shown in Table 1. The data in Table 1 was collected from references [18, 19]. In comparison with thermal or kinetic energy, electromagnetic energy is not limited by space or time. The RF wave is available both indoors and outdoors, in rural and urban areas, throughout the day. Despite its low power density in the environment, an intentional source can be added for more efficient power transmission and a boosting circuit can be built to suit the requirements of the load application. This feature promotes research to realize RF WPH technology through applications such as wireless sensor networks (WSNs) and Internet of Things (IoT).

Table 1

Overview of alternative sources of energy to replace batteries

Source	**Power density**	**Harvesting tech.**	**Advantages**	**Disadvantages**
Solar	Indoor: 10 μW/cm^2 Outdoor: 10 mW/cm^2	Photovoltaic	High power density Mature	Not always available Required exposure to light (not implantable) Expensive
Vibration	Human: 4 μW/cm^2 Industrial: 100 μW/cm^2	Piezoelectric Electrostatic Electromagnetic	Implantable High efficiency	Not always available Material physical limitation
Thermal	Human: 30 μW/cm^2 Industrial: 1–10 mW/cm^2	Thermoelectric Pyroelectric	High power density Implantable	Not always available Excess heat
RF	GSM: 0.1 μW/cm^2 WI-FI: 1 mW/cm^2	Antenna	Always available Implantable	Low density Efficiency inversely proportional to distance

Fundamentals of RF transmission

Understanding electromagnetic waves is important to design an RF WPH system. The behavior of electromagnetic waves varies according to the distance, frequency, and conducting environment. Depending on the requirements of the application, the designer needs to select suitable parameters for electromagnetic waves to obtain best results.

The loss of power in space can be characterized by free space path loss (FSPL), which is the loss of signal power during propagation in free space. Calculating FSPL requires information about the antenna gain, frequency of transmitting wave, and

distance between the transmitter and receiver.

The behavior of electromagnetic waves depends upon the distance from the transmitting antenna. These characteristics are categorized into two segments: far-field and near-field [20]. While the electromagnetic wave pattern at the far-field is relatively uniform, in the near-field, the electric and magnetic components are very strong and independent such that one component can dominate the other. The near-field region is considered as the space that lies within the Fraunhofer's distance and the far-field region lies outside the Fraunhofer's distance. The distribution of the near and far field regions is illustrated in Fig. 2. The Fraunhofer's distance is defined as

$$d_f = \frac{2D^2}{\lambda},$$

(1)

where d_f is the Fraunhofer's distance, D is the maximum dimension of the radiator (or diameter of the antenna), and λ is the wavelength of the electromagnetic wave. Although the Fraunhofer creates a boundary region, the actual transition between regions is not distinct. Inside the near-field, the space from the antenna to a distance of $\sqrt[3]{\frac{D}{2\lambda}}$ is a non-radiative/reactive near-field region, where E and H fields are not in phase, creating energy distortion. As we propagate forward in this region towards the far-field, we encounter a radiative near-field or Fresnel region, where the reactive behavior of electromagnetic waves is not dominant but the phases of E and H fields still vary with distance.

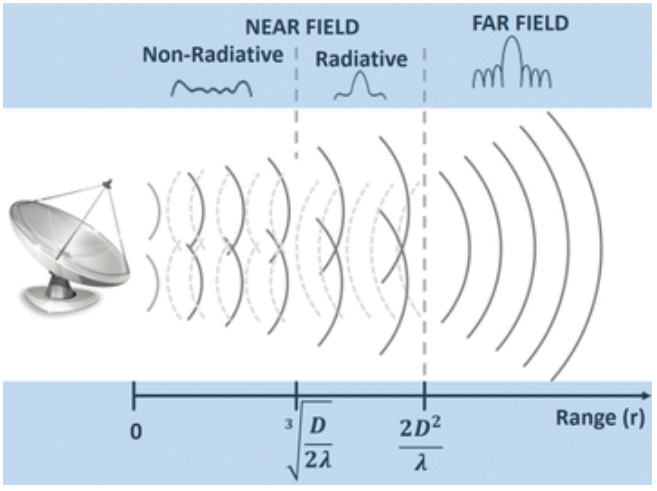


Fig. 2

Distribution of near field and far field regions in space

For a transmitter–receiver antenna in the far-field free space, the power propagation at the receiver antenna can be expressed as

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi R)^2},$$

(2)

where P_R is power at the receiver antenna; G_R is receiver antenna gain relative to the isotropic source (dBi); λ is the wavelength of the electromagnetic signal, which is equal to the speed of light in vacuum divided by the signal frequency, $\lambda = \frac{c}{f}$; and k = 2π/λ is the wave number. From the above formula, the FSPL, P_L for far-field can be inferred as

$$P_L = \frac{P_T}{P_R} = \frac{(4\pi R)^2}{G_T G_R \lambda^2} = \frac{(4\pi f R)^2}{G_T G_R c^2} = \frac{4}{G_T G_R}(kR)^2$$

(3)

or

$$P_L\,(dB) = 20\log_{10}(f) + 20\log_{10}(R) + 20\log_{10}\left(\frac{4\pi}{c}\right) - G_T - G_R$$

(4)

In case f is measured in MHz, distance R is measured in km, and gain G_T and G_R are measured in dBi, the above function becomes

$$P_L\,(dB) = 20\log_{10}(f) + 20\log_{10}(R) + 32.44 - G_T - G_R$$

(5)

By using the path loss equation, it is possible to indicate the signal power at the far field region. However, this equation does not present all the factors that affect the propagation process such as reflection, diffraction, absorption, etc.

In contrast to the uniform far-field wave, the electric and magnetic fields behave unusually in the near-field. The relationship between electric and magnetic waves in the near-field varies unpredictably with time and space and is too complicated to predict. All these factors make estimating the power density at this range problematic.

The FSPL estimation process is critical to design the energy-harvesting unit. Being informed about the amount of power that the system is required to handle helps the designer in choosing the right technology and method.

Since the electromagnetic field (EMF) is widely used for a variety of purposes, there must be a standard to ensure the safe operation of EMF devices. For this purpose, the International Electrotechnical Commission [21] established international standards and frequency limits for EMFs. For safety measures, there must be a separate emission and immunity standard for each class of application including broadcast, communication, military, medical, and household appliances.

On the other hand, radiation exposure must be considered carefully, especially in biomedical applications. EMFs at different spectrums affect the human body differently. Between 1 MHz to 10 GHz frequency, EMF possibly penetrates through tissues and produce heat because of energy absorption. EMFs over 10 GHz are strongly blocked by the skin, and then the heat created causes damage such as eye cataracts or skin burns if the field density is above 1000 W/m^2. Hoping to prevent negative health effects when utilizing EMF applications, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) developed general guidelines for EMF exposure limits recognized under the World Health Organization (WHO). To date, there have been no consistent reports corroborating that lasting exposure to EMF shortens one's life span or induces adverse health conditions. However, for safety issues, RF emission power and frequency must be considered carefully to avoid unwanted damages.

Wireless power harvesting evaluation metrics

There are various parameters that need to be evaluated, which decide the performance of a WPH design. Evaluation merits change depending on different applications. Nevertheless, critical values such as efficiency, sensitivity, operation distance, output power are defined as standards to make comparisons. However, tradeoffs exist between these values such as operation distance and overall efficiency. Moreover, besides this merit, other manufacturing auxiliary factors like low cost, maturity of fabrication process, and bulk manufacturing availability are also paramount.

Operation range

Operation distance is mostly related to operation frequency. In fact, transmission at high frequencies is attenuated by atmospheric conditions more than at low frequencies while low frequency penetrates deeper through matter. Therefore, if the application of WPH is for implantable devices, then the transmitting frequency should not exceed the megahertz range.

RF-DC power conversion efficiency (PCE)

This is the ratio between the amount of power applied to the load and that retrieved by the antenna. Generally, the RF-DC PCE covers the efficiency of the rectifier, voltage multiplier, and storage elements. PCE can be simply calculated as the ratio of power delivered to the load to the retrieved power. RF transmission loss in space is not considered in this term.

$$\eta_{PCE} = \frac{P_{load}}{P_{retrived}}, \quad (6)$$

where P_{load} is power delivered to the load and $P_{retrieved}$ is harvested power at the antenna. Factors that determine the value of PCE include parasitic effects, leakage in the circuits, design topologies, and nonlinear thresholds of electrical components.

Resonator Q factor

The Q factor is generally defined as a dimensionless value that describes how strong the resonance is and the bandwidth of resonance [22]. In electric circuits, the Q factor represents how much the peak voltage increases when the system resonates at resonant frequency. From this concept, the equation of Q factor can be express as the formula below [23]:

$$Q = 2\pi \frac{Energy\,stored}{Energy\,dissipated\,per\,cycle} or\ Q = \frac{f_c}{\Delta f}$$

(7)

From the equation above, it is inferred that a high Q factor comes with a narrow resonant bandwidth, but high voltage gain is obtained at resonance. Further, this equation also indicates that the Q factor is inversely proportional to the energy dissipated per cycle. The specific Q factor for capacitor C and inductor L at frequency ω is given by

$$\text{Capacitor Q factor: } Q_C = \frac{1}{\omega R_c C} = \frac{X_c}{R_c},$$

(8)

$$\text{Inductor Q factor: } Q_L = \frac{\omega L}{R_L} = \frac{X_L}{R_L},$$

(9)

where R_C is the series resistance of capacitor and R_L is the series resistance of inductor. From the equations of Q_C and Q_L, we note that resistive component is the cause of power dissipation. Additionally, in an electrical circuit, energy loss can be reduced by adding reactive components such as capacitors or inductors and minimizing resistive components. Since obtaining a high Q factor is a usual consideration in designing WPH systems, this feature is typically included in the impedance matching network design.

Sensitivity

Sensitivity of a WPH system is defined as the minimum limit of incident power that is required to trigger the operation of the system. Sensitivity is quantified as follows:

$$Sensitivity\ (dBm) = 10\log_{10}\left(\frac{P}{1mW}\right),$$

(10)

where P is the minimum power the system requires to perform a task.

The threshold voltage of CMOS technology affects sensitivity. A lower threshold CMOS is more sensitive but comes with more leakage current, which reduces the overall efficiency.

Output power

Usually, the outcome of a WPH system is DC power, which is characterized by load voltage V_{DD} and current I_{DD}. Measuring open-load voltage demonstrates the performance of WPH in general since V_{DD} and I_{DD} depend on load impedance. If the load is a sensor, V_{DD} is more important than I_{DD} while in applications like electrolysis or LED, current is the dominant parameter.

Recent advances in wireless power harvesting

Antenna/rectenna design

Gain, resonance frequency, bandwidth are parameters that characterize the performance of an antenna. Assuming an unobstructed space and isotropic transmitting source, the spreading of the waves in all directions is uniform. Thus, the power per unit area at a distance from the source is inversely proportional to the square of the distance:

$$S_{isotropic} = \frac{P_T}{4\pi R^2},$$

(11)

where R is the distance from the source, S is power per unit area at the distance R, and P_T is the transmitted power. However, it is important to note that antennas do not always transmit power spherically (isotropic antenna), they also transmit energy in some specific directions according to their designs. The ratio between the maximum power density of an antenna at a given distance to the power density of an optimal omnidirectional or isotropic antenna at the same distance, radiating the same power, is known as antenna gain (G). This parameter represents the directivity of an antenna. Since power density (S) is non-directional, the definition of S was developed as a function of direction i.e. S (θ, φ). Consequently, the gain of the antenna is a directional function as well. It is defined as the ratio of the antenna's power density in a given direction to the power density of an isotropic antenna as formula below

$$G(\theta,\varphi) = \frac{\mathrm{S}(\theta,\varphi)}{S_{isotropic}} = \frac{4\pi R^2 S(\theta,\varphi)}{\mathrm{P}_t},$$

(12)

Thus, the power density at a distance R from an antenna in general is given by

$$S = \frac{P_T G_T}{4\pi R^2}, \quad (13)$$

where P_T is the transmitted power by the antenna and G_T is the transmitting antenna gain. It is known that an ideal isotropic antenna has $G_T = 0$ dBi. The aforementioned formula is also applicable to receiving antennas. Specifically, for power harvesting applications, a receiving antenna, which constitutes a rectifier, is called a rectenna.

Preference for a high gain antenna depends on the application requirements. In case of RF transmission, if the positions of source and receiving antennas are known, then a high gain rectenna is advantageous. On the other hand, if the positions of the source and receiving antenna are relatively uncertain, a low gain antenna is preferable in order to collect signals from various directions simultaneously.

Every antenna has its own optimal operation frequency known as resonance frequency (Fig. 3). The resonance frequency is determined by the capacitance and inductance characteristics of the antenna. As frequency increases, inductive behavior becomes dominant and capacitance decreases. The frequency at which the inductance and capacitance nullify each other, minimizing the impedance of the antenna, is called the resonance frequency.

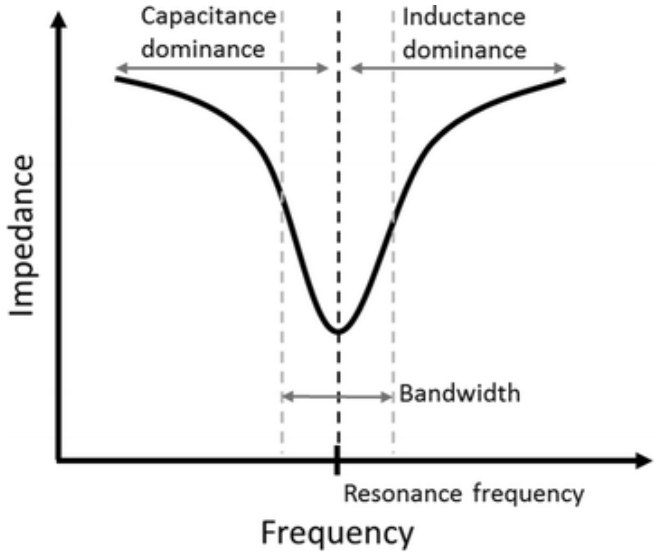


Fig. 3

Correlation between impedance and resonance frequency, and bandwidth of an antenna

The capacitance and inductance are functions of the frequency and physical size of the antenna. The larger the dimensions of the antenna, the lower the resonance frequency. Therefore, transmitting and receiving low frequency waves requires a large aperture, which is not suitable for small device applications. The antenna designed in [24] has a sensitivity as low as −35 dBm (0.32 μW), but the tradeoff is a large size aperture measuring up to 64.68 cm^3 (7 × 7 × 1.32 cm).

The bandwidth of an antenna is the range of frequencies in which the antenna can operate efficiently. A wide bandwidth antenna can collect signals from a wider range of frequencies than a narrow bandwidth antenna. Hence, a wide bandwidth antenna is advantageous in retrieving incident energy but presents a high risk of interference by noise through unwanted frequencies (Table 2).

Table 2

Comparison of published work regarding power-harvesting antennas

Ref.	Type	Gain (dBi)	Freq. (GHz)	Dimension (mm)	Sensitivity	RF-DC PCE

Ref.	Type	Gain (dBi)	Freq. (GHz)	Dimension (mm)	Sensitivity	RF-DC PCE
[25]	Air-substrate patch	7	2.45	261 × 5	–	30% @ 1 μW/cm^2
[26]	Polarization patch	–	5.1–5.8 5.8–6.1	90 × 160	–	23.8%–31.9% 22.7%–24.5%
[27]	Patch	–	2.45	100 × 70	–	73.9% @ 207 μW/cm^2
[28]	Dual-linearly polarized patch	7.45–7.63	2.45	70 × 47.5	–	78% @ 295.3 μW/cm^2
[29]	Microstrip	5.3	160	–	–	8.5% @ −2.46 dBm
[30]	Patch	–	1.9–3.2	40 × 40 × 0.8	20 μW/cm^2	70% @ 50 μW/cm^2
[31]	Patch	−20.20	0.915	Π × 6 × 1.584		~ 60%
[32]	Patch, metal strip	4.33 6.64	4.9 5.9	68 × 34	–	65.2% 64.8%
[33]	Stack differential	–	5.8	120 × 40	–	44.1% @ 0.041 W/m^2
[24]	Cross dipole	–	1.8–2.5	70 × 70 × 13.2	−35 dBm	55% @ −10 dBm
[34]	Dual-polarized patch	–	2.45	100 × 100 × 3.8	–	82.3% @ 22 dBm
[35]	1 × 4 quasi-Yagi	10.9 13.3	1.8 2.2	300 × 300 × 1.6	–	40% @ 455 μW/cm^2
[36]	Dipole	–	0.915 2.45	60 × 60 × 60	1 μW/cm^2	48% @ 0 dBm 39% @ 0 dBm
[37]	Microstrip	8.6	2.45	–		83%

Ref.	Type	Gain (dBi)	Freq. (GHz)	Dimension (mm)	Sensitivity	RF-DC PCE
[38]	Patch	4	2.45	–	–	70%
[39]	Patch	2.19 3.6	2.45 5.8	40 × 43	–	65% @ 10 mW/cm^2 46% @ 10 mW/cm^2

Communication antennas have been studied for decades. However, power-harvesting antennas are currently in the developmental stage. At first, antenna classification was based on design characteristics and applications. It originally included wire antennas, aperture antennas, printed planar antennas, and reflector antennas. An illustration of some examples of antennas is shown in Fig. 4. To date, the growth in technology has paved the way for a variety of antenna design and fabrication methods for making it more compact and mature.

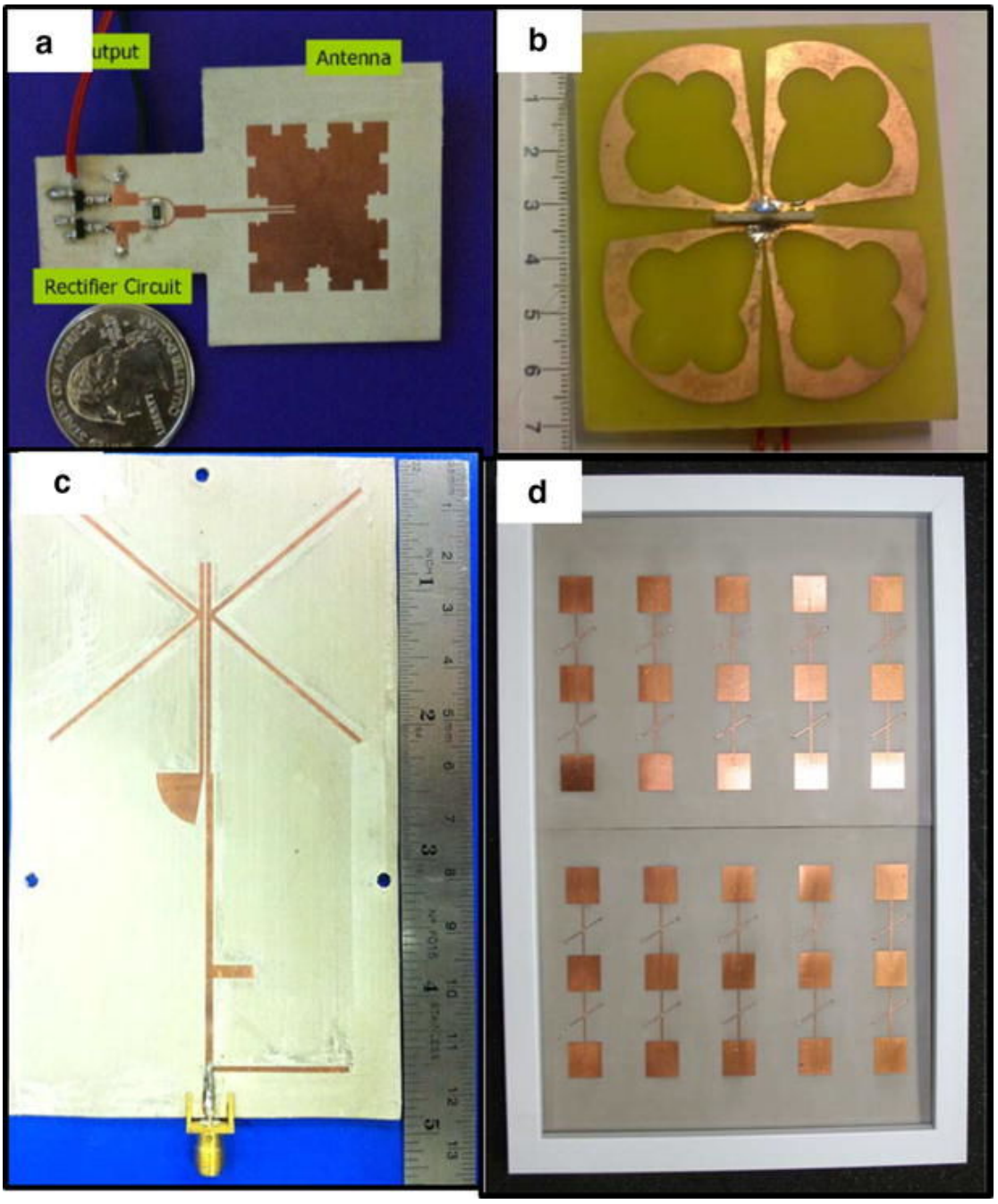


Fig. 4

Types of antennas **a** 2.45 GHz patch antenna with rectifier [38]. ©2010 IEEE. All rights reserved; **b** Planar dual-polarized antenna [24]. ©2015 IEEE. All rights reserved; **c** Microstrip antenna [37]. ©2012 IEEE. All rights reserved; **d** Array of stacked differential patch antenna [33]. ©2015 IEEE. All rights reserved

The plate antennas are popular and have many applications [27, 34, 38]; on-chip antennas are preferred for small and compact applications. Recently, many publications addressed wide-band and multi-band antennas. It has been proven that narrow-band antennas offer high energy conversion efficiencies but can only retrieve a limited amount of energy. On the other hand, wide-band or multi-band frequency antennas can retrieve more RF energy in space. However, the tradeoffs are low overall efficiency and large aperture. In [32], antennas with a resonance frequency of 4.9 and 5.9 GHz were designed with PCEs of 65.2 and 64.8%, respectively. Further work by Lu et al. [26] on polarization antennas supports the assertion that expanding the bandwidth of an antenna leads to increasing the amount of power harvested. In this work, the demonstration of broadband polarization antennas with three separate modes allows the antenna to operate in a wider range of frequencies. One common mechanism in the aforementioned works is the control of the antenna configuration by switching the diodes on and off, thus altering its resonant frequencies. However, since it uses separate modes for different frequencies, this antenna is not able to simultaneously resonate at two frequencies. On the other hand, the antenna presented in [39] is capable of operating at 2.45 and 5.8 GHz, simultaneously, providing 2.6 V output with a PCE of 65% and power density of 10 mW/cm^2.

The main purpose of aligning antennas in arrays is to enhance the antenna gain and obtain high voltage/current. Array antennas are preferred over large aperture antennas because they do not require large breakdown voltage diodes to operate. Antenna arrays can be connected before or after rectification. The first configuration enhances the retrieved power at the main beam while the second configuration expands the ability to retrieve power from various angles away from the main beam [40]. In case the RF waves are combined before rectification, the rectifier requires a large breakdown diode. If RF waves are combined after rectification, combining DC current becomes problematic. Antenna arrays can be connected in series or parallel to obtain high voltage or large current. Nonetheless, expanding the arrays yields better output but this might cause a deduction in conversion efficiency [33].

For demonstrating antenna arrays, Sun et al. [35] invented a T-junction to connect four quasi-Yagi antennas together. The advancement in this work was that the T-junction was flexible in changing from 1 × 4 array to 2 × 2 array topologies. Consequently, the system was able to operate at an ambient power level as low as 455 $\mu W/cm^2$ while obtaining 40% PCE.

Impedance matching network

In low-power consumption electrical systems, power leakage during transmission may lead to energy insufficiency. In these circumstances, adding an impedance matching network (IMN) ensures that the maximum power transfers between the RF source and load. For WPH applications, the receiving antenna is considered as the source while the rectifier/voltage multiplier is considered as the load. It is acknowledged that in DC, power transfer is optimum when the resistances of the source and load are indistinguishable. In an RF circuit, the impedance is referred to instead of resistance. An impedance mismatch between the source and load creates reflected power flow in the circuit that lowers the efficiency of the system. As its name indicates, the IMN ensures that the impedance of the source and load are identical by adding reactive components in between.

There are three basics matching configurations i.e. L, T and π matching networks (Fig. 5). The L matching is commonly used since it typically has two components, which simplifies the designing and controlling process. Additionally, the L matching networks do not alter the quality factor (Q) of the circuit.

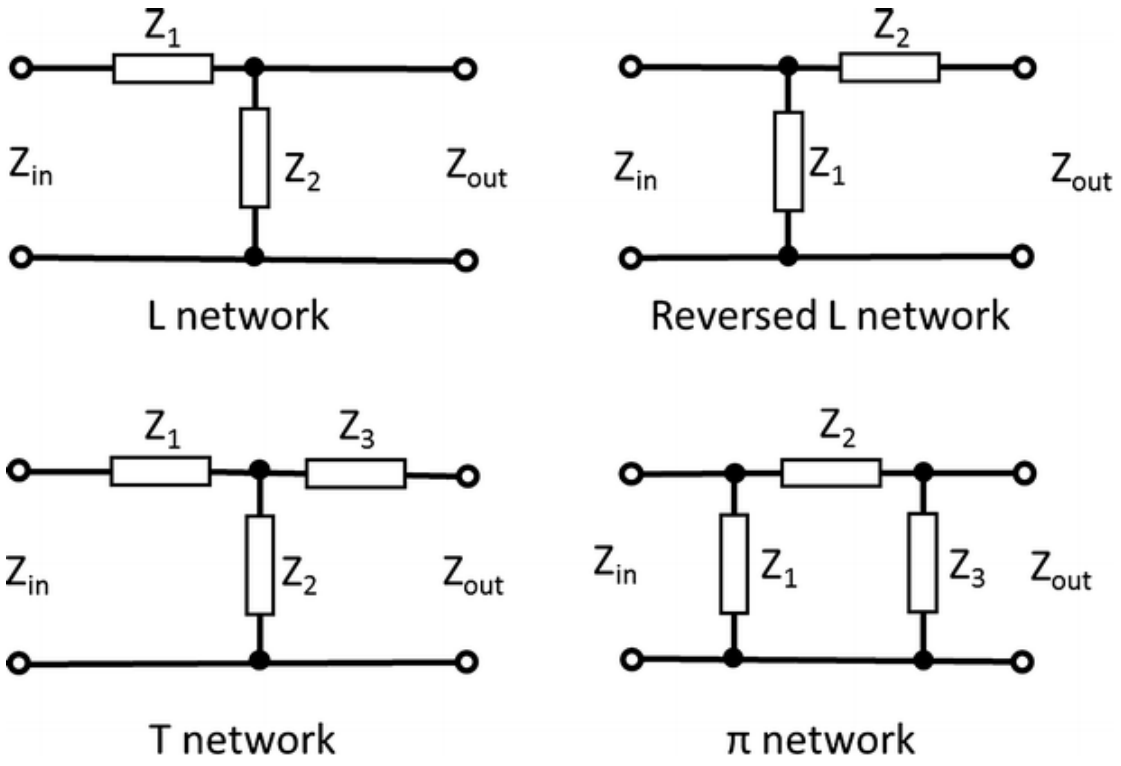


Fig. 5

Configuration of common impedance matching networks

The T and π matching configurations are more complex than the L network. Furthermore, organizing the T and π configurations into multiple stages will retain the final matching results but will change the Q factor. This strategy is useful in improving voltage boost.

There are tradeoffs between the attributes of an IMN, which include frequency, bandwidth, adjustability, and complexity. For instant, in [41], the suboptimal impedance matching and multiport ladder matching methods were introduced to enhance the

matching performance and harvested power of antennas, respectively. However, the tradeoff was that implementation of these configurations required more components than traditional matching networks, thus, escalating the circuit's complexity.

Etor et al. [42] designed an IMN for THz frequencies applications using transmission lines and self-designed metal–insulator-metal diodes instead of lumped components. Moreover, fixed IMN and tunable IMN [43, 44, 45] were introduced as a technique for better matching with wide-band and multi-band antennas.

Rectifier/voltage multiplier

RF energy extracted from free space usually possesses low power density since the electric field power density decreases at the rate of $1/d^2$, where d is the distance from the RF source [46]. Therefore, a power amplifier circuit is required that yields enough DC energy from the electromagnetic waves to drive the loads. This gives rise to two possibilities, if the power consumption of the load is lower than the average power harvesting, the electronic devices at the load may work continuously; otherwise, if the load consumes more energy than the power harvesting circuit can generate, the devices cannot work continuously [47].

Rectifying is the most popular application of diodes, which refers to the conversion of AC current to DC current. In terms of power harvesting application, the RF signal retrieved in the antenna has a sinusoidal waveform. The signal after transformation through IMN would be rectified and boosted to meet the power requirements of the application.

The most fundamental topology of the rectifier is the half-wave rectifier that comprises of a single diode D1 (Fig. 6a). When AC voltage transfers through D1, only the positive cycle remains and the negative cycle is cutoff; thus, it diminishes half of the AC power. Moreover, the output V_{out} is discontinuous since the negative cycle is cutoff. Despite its simplicity, a half-wave rectifier is usually inadequate for common applications. Hence, a full-wave rectifier is more preferable. The circuit design of the full-wave rectifier is shown in Fig. 6b. During the first negative cycle of AC input, diode D1 is conductive and capacitor C1 is charged to the corresponding energy level of V_{peak} of the input. Then, at the next positive cycle, diode D1 is blocked, diode D2 is conductive so that capacitor C2 is also charged. In consequence, the output V_{out} would see two capacitors in series (each one is storing a voltage of V_{peak}). Thus, V_{out} is twice V_{peak}. Therefore, this topology is more stable and efficient than the half-wave rectifier. There is also a bridge rectifier that rectifies both positive and negative cycles of the AC input but retains $V_{out} = V_{peak}$ by alternatively blocking pairs of diodes D1, D4 and D2, D3 (Fig. 6c).

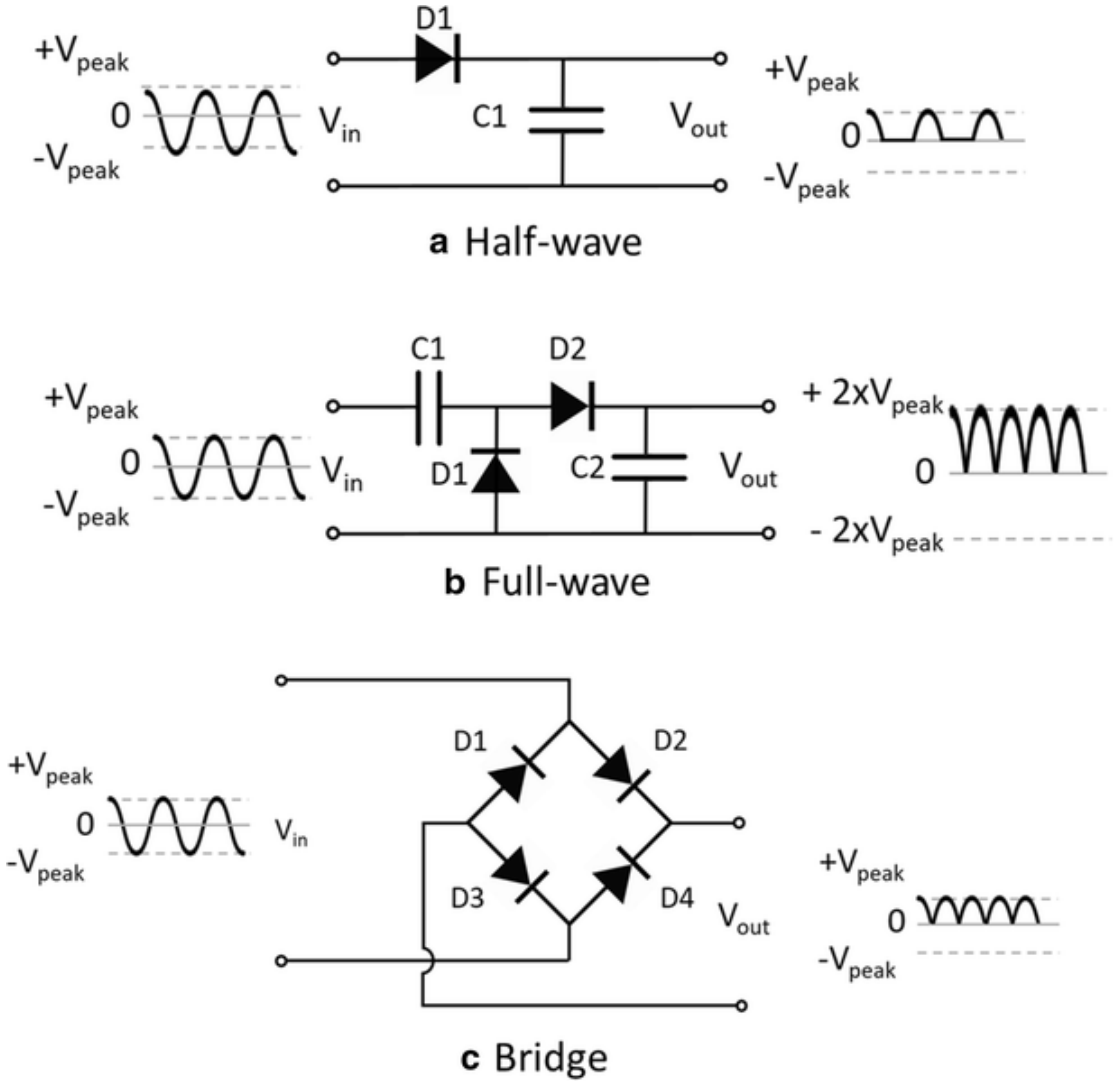


Fig. 6

Some common topologies of a rectifier

Voltage multiplier is a special type of rectifier circuit that converts and boosts AC input to DC output. In some case where the rectified power is inadequate for the application, there is a need for boosting the output DC by stacking single rectifiers into series, forming the voltage multiplier [48]. Several configurations of the voltage multiplier are shown in Fig. 7. The most fundamental configuration is the Cockcroft–Walton voltage multiplier (Fig. 7a). This circuit's operational principle is similar to the full-wave rectifier (Fig. 6b) but has more stages for higher voltage gain. The Dickson multiplier in Fig. 7b is a modification of Cockcroft–Walton's configuration with stage capacitors being shunted to reduce parasitic effects. Thus, the Dickson multiplier is preferable for small voltage applications. However, it is challenging to obtain high PCE due to the high threshold voltage among diodes creating leakage current, thus reducing the overall efficiency. Additionally, for high resistance loads, output voltage drops drastically leading to low current supply to the load. A summary of recent works related to voltage multiplier is shown in Table 3.

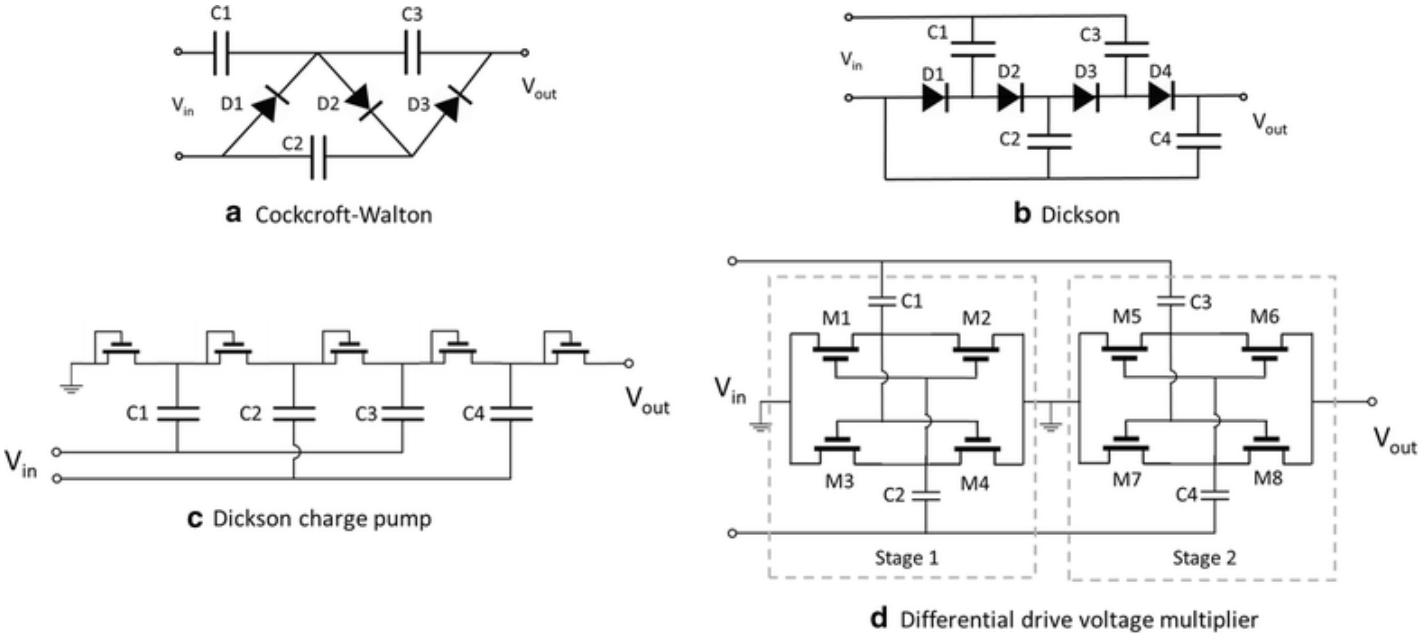


Fig. 7

Common voltage multiplier configurations: **a** Three stages Cockcroft–Walton voltage multiplier, **b** Four stages Dickson voltage multiplier, **c** Four stage Dickson voltage multiplier using CMOS technology, **d** Two stages voltage multiplier comprised of differential drive unit

Table 3

Published work comparison regarding voltage multiplier

Ref.	Rectifier topology	No. of stage	Freq. (MHz)	Tech.	Range (dBm)	Maximum PCE	Size
[51]	Differential	2	433	0.18 µm CMOS	0–20	74% @ 2 dBm	–
[52]	PMOS transistors	7	900	40 nm CMOS	–	44% @ > 390 mV	0.04 mm^2
[53]	Half-wave	4	900	0.18 µm CMOS	–	37.42% @ 390 mV	–
[54]	Comparator-based/active-diode	3	13.56	0.18 µm CMOS	8–15	67.9% @ 12.8 dBm	–
[55]	Dickson	3	13.56	250 nm CMOS	–	72%	0.13 mm^2
[56]	–	–	915	0.13 µm CMOS	−21.6	22.6% @ −16.8 dBm	0.186 mm^2

Ref.	Rectifier topology	No. of stage	Freq. (MHz)	Tech.	Range (dBm)	Maximum PCE	Size
[57]	–	–	900, 2400	130 nm CMOS	–	41% @ −20.6 dBm	–

The MOSFET (metal–oxide–semiconductor field effect transistor) technology is overcoming the limitations of diodes and becoming an alternate solution for rectifying and boosting. Owing to MOSFET technology, Dickson multiplier can be integrated together in integrate circuits (IC) by replacing diodes with NMOS as shown in Fig. 7c. Relatively low threshold voltages and high PCEs are features of this design. Moreover, differential drive voltage multiplier (Fig. 7d) is widely used because of its low leakage current and potential for further modification for specific applications. A detail explanation and analysis is presented in [49, 50].

There is a strong relationship between the number of stages of a voltage multiplier and its sensitivity and efficiency. As the number of stages increase, there is more loss across each added stage. However, the tradeoff is higher voltage multiplication and small threshold voltage at the first stage. On the other hand, a voltage multiplier with a few stages has less voltage drop between its stages but requires higher threshold voltage for all stages to work simultaneously. For this reason, a voltage multiplier becomes more sensitive when a large number of stages are present and becomes more efficient at fewer stages. This tradeoff feature was analyzed in several researches [53, 58]. Therefore, the optimal number of stages should be considered depending upon the application targets.

Pros and cons of Schottky diode and CMOS technology

Rectifying elements such as diodes or transistors are indispensable components of the rectifier/voltage multiplier block, which determine operation frequency and power-conversion efficiency. Traditionally, a Schottky diode was used because of its low threshold voltage. Moreover, there are also Esaki (tunnel) diodes, metal–insulator–metal (MIM) diodes, and spin diodes with recent technology enhancements that make it more mature. Particularly, the Esaki diode can operate at very high frequency with fast response because of its low parasitic elements. Moreover, the MIM diodes technology makes integration with CMOS process possible, which is a limitation of Schottky diodes. Spin diodes offer lower threshold voltages than Schottky diodes.

There are several parameters that need to be considered when choosing a diode for designing a voltage multiplier. These include RF to DC power conversion efficiency, parasitic efficiency, and matching efficiency. When it comes to microwatt applications, Schottky diodes face some limitation in RF-DC conversion efficiency because of their high zero-bias junction resistance [59]. However, owing to recent developments in technology, if the retrieved power is less than −30 dBm (1 μW), then the low-barrier SMS7630 and VDI W-Band ZBD diodes are recommended due to their low parasitic power losses and low power dissipation in the matching network [60].

Recently, many publications have moved toward CMOS processes, since they not only assist in custom designing in electronics but are also more sensitive to low operation voltages than traditional Schottky diodes. Many researches focus on modifying present rectifier and voltage multiplier topologies to achieve higher gain, sensitivity, efficiency [52, 55, 56, 57, 61]. For instance, the voltage multiplier achieved maximum 11% PCE at −24 dBm (4 μW) in [62] and 41% PCE at −20.6 dBm (8.7 μW) input power in [57]. While the majority of publications utilized 0.18 μm CMOS technology in their work, [52] applied commercial 40 nm CMOS process to build a low-voltage operation voltage multiplier that reached 44% PCE at 390 mV input. Hwang et al. [54] applied reducing reverse loss to minimize the reverse leakage loss in the rectifier, thus increasing the overall efficiency.

Similar to Schottky diodes, the number of stages directly dictates the performance efficiency in the task of designing a custom CMOS voltage multiplier. A basic assumption when using transistors is that the retrieved RF signal from the antenna must be high enough to trigger the transistors on and off. Different voltage multiplier topologies possess different features and characteristics. However, as long as transistors are used in the design, there is considerable amount of voltage drop among transistors. It has been observed that the major cause of rectified voltage drop is the threshold loss. If the number of stages increases, the threshold voltage at the transistors also adds up, requiring the higher amplitude RF signal to trigger the transistors [62]. Therefore, the number of stages in the majority of publications usually does not exceed 10.

Designing and optimizing the WPH system

The efficiencies of individual modules and the integration of all modules together constitute the total efficiency of a WPH system. As a consequence, the only way to optimize the total efficiency is to maximize efficiencies of each module and consolidate them in harmony. Commonly, several tests and adjustments need to be done to obtain an optimized WPH system. The work flow of designing a WPH system is described in Fig. 8.

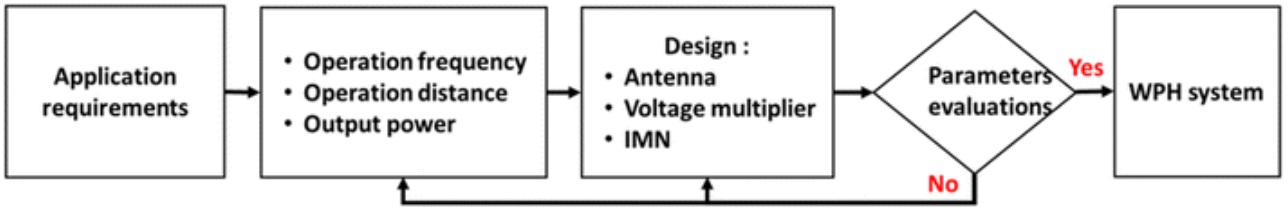


Fig. 8

WPH system's designing protocol

Firstly, choosing the appropriate operation frequency to the application's requirement critically dictates the efficiency of the WPH system. Secondly, the operation range also need to be specified. Long range (far-field) power harvesting or transmission requires high frequency such as 2.45, 5.24 GHz, whereas short range (near-field) applications requires electromagnetic waves at frequencies in the megahertz range. Additionally, for power harvesting in dense environment different from air, very low frequency (~kHz) is preferable. Besides the operation frequency and distance, the required output power and voltage determines the suitable topology of the voltage multiplier.

Based on the operation and application, the antenna's design has to match the gain, frequency and size. Choosing the right rectifying element is also critical. For rectifier and voltage multiplier modules in general, the dependence of RF-DC PCE on frequency and output load was discussed in [50]. In addition, it is obligated to have a correct-tuned IMN for maximum power transfer inside the WPH circuit.

Detailed features of individual modules of the WPH system are explained and discussed in the previous sections. The problem of optimizing the WPH system becomes the game of defining the goals and integrating individual modules in harmony to archive the goal.

Applications

RF power harvesting in medical and healthcare

In order to deploy WPH in the real world, power consumption rate of the device should be less than the harvested power. Since retrieved power is unstable and difficult to predict, an energy storage module is highly recommended to enhance its consistency. If the WPH is integrated to the device as a single system on chip, the total size of the system would be reduced significantly.

The first wireless battery-free bio-signal processing system on chip [63] was introduced by [64]. This system was able to monitor various bio-signals via electrocardiogram (ECG), electromyogram (EMG), and electroencephalogram (EEG). The total size of the chip was 8.25 mm^2. This chip only consumed 19 μW to measure heart rate. The power module of this system comprised an RF WPH that was supported by a thermoelectric generator, which together supplied a voltage of 1.35 V. Table 4 presents the performance of several health monitoring system on chips (SoCs). The majority of chips have the advantages of small size, low voltage supply and low power consumption which is applicable to be integrated with WPH technology.

Table 4

Power consumption of published SoC devices

Ref.	Sensors	Operation voltage (V)	Chip power (μW)	Size (mm)
[21]	Intraocular pressure (IOP)	–	0.0053	0.5 × 1.5 × 2.5
[65]	ECG, Bio-impedance	1.2	345–374	7 × 7

Ref.	Sensors	Operation voltage (V)	Chip power (μW)	Size (mm)
[66]	ECG	1.2	32	5 × 4.7
[64]	ECG, EMG, EEG	1.2	19	2.5 × 3.3
[67]	ECG, thoracic impedance variance (TIV)	1.2	2400	5 × 5
[68]	EEG	1	77.1	2.5 × 2.5
[69]	Temperature, pressure	0.4/0.5	7.7	2.2 × 2.7
[70]	Neural, ECG, EMG, EEG	1	500	2.5 × 1

It is a fact that a considerable amount of TV broadcast signals never reach the TV. Fortunately, WPH technology can harness this wasted energy without causing any effect on the TV broadcasting quality. In this context, Nishimoto et al. [71] have explored this potential source of energy to remove batteries from temperature monitoring WSNs. Since the power density of TV broadcasts is relatively weak, an array antenna was designed to collect multi-frequency waves. Compared to the antenna array designed in [72], the antenna rectifying efficiency obtained was higher by 50% in the frequencies between 15 and 800 MHz. This design is reported to successfully measure and transmit data every 5 s.

In some research experiments where free movement is unavoidable, stimulation signal and response data has to be delivered and collected wirelessly. In these circumstances, RF WPH is a superior choice in comparison with inductive coupling transmission technology to power the wireless system. Cobo et al. designed an implantable micro-pump that is powered by inductive coupling coils. Even though this work has obtained high efficiency power transmission, the operation range is limited to a few centimeters from the source. On the other hand, in [73], the RF electromagnetic waves were deployed to power optogenetic microneedles to be wirelessly injected into mice. The design of WPH in this work was able to retrieve 4.08 mW power at a distance of 1 m from the 7.9 W source at a frequency of 910 MHz. Another rectenna was built for mounting on the mice' heads for deep brain stimulation (DBS) devices [31]. In this system, the power-harvesting module retrieves 0.254 mW DC power at a maximum operation distance of 20 cm. With this available power, the DBS device generates 200 μA pulses at 130 Hz. The above results show that RF WPH technology offers a better operation range than traditional inductive coupling power transmission technology. It is now possible to harvest sufficient power to run low-power consumption devices in the range of meters. The noninvasive bio-telemetry system for monitoring and investigating various health indexes is a promising field for WPH technology. Cheng et al. [74] introduced a power harvesting design that included a loop antenna to be attached to the pig eye with 31% PCE and output power up to 2.10 mW. Additionally, in vivo experiments, using WPH technology to supply medical devices for implantation in rapid eyes was demonstrated without recorded side effects [63, 75].

Wireless power harvesting network (IoT/WSN)

Along with the development of the micro-electro-mechanical systems (MEMS) technology, wireless sensor networks have gained widespread popularity in recent years. This field has achieved several milestones and is still developing further. WSNs applications widespread from smart house, healthcare to industry and military. In addition to the issues of sensing reliability, communication protocol, and network services, energy is a critical concern in WSNs [76]. Sensor nodes of WSNs are low power devices, and minimization of energy consumption and application of WPH to replenish power storage elements are two concurrent schemes to maximize the network lifespan. Recently, several researches were done to find optimized approaches to power WSNs including RF power harvesting [77, 78, 79, 80, 81].

Energy is the greatest challenge in deploying WSNs [82]. Applying RF energy to recharge the batteries is one approach to enhance the lifespan of WSNs [83, 84]. Lee et al. [85] is an example of an RF charger utilizing WPH technology. The system was able to work with a minimum input power of −10 dBm (0.1 mW) in the frequency range from 1.96 to 1.98 GHz to charge a 5 V super-capacitor. Maximum RF to DC power conversion efficiency is 81% at 6 dBm (3.98 mW). Gudan et al. [86] also designed a WPH system to charge a NiMH battery using either ambient Wi-Fi or Bluetooth signals. With the sensitivity down to −20 dBm, this system was capable of charging a battery to 5.8 μJ after 1 h.

Table 5 lists some low-power consumption sensor applications that can be integrated with a WPH module. The majority of these sensors were powered by battery with limited lifetime. Once WPH technology is implemented with these applications, it could be used in as a wireless sensor node. In particular, the work presented in [81] utilized RF power harvesting into WSNs for building's structure monitoring. In this work, far-field RF powered wireless sensors were developed with novel data transmission approach to detect humidity, temperature and light inside a building. Results show at a distance of 1 m from 3 W source, the sensor node received 3.14 mW power through air, 1.53 mW of power through 2 inches of brick, 2.88 mW through wood and 0.7 mW through 2 inches of steel. This amount of power is sufficient for the sensors presented in [88, 89, 90, 91]. This result indicates the applicability of RF WPH toward WSNs.

Table 5

State-of-the-art published sensors for WSNs

Ref.	Sensors	Total power consumption (mW)	Supplied voltage (V)	Power source	Applications
[87]	Pressure	12.69		Battery	Tire pressure monitoring
[88]	Pressure	0.03		Battery	Blood pulses monitoring, small vibration recording
[89]	Temperature	0.0068	1.5-2		RFID, implantable devices
[90]	Temperature	0.065	2.5–5.5		Room temperature monitoring
[91]	Temperature	0.000071	1.2	Battery	Environment monitoring
[92]	Gas	24		DC power source	C_2H_5OH detection
[93]	Gas	2	5		Smart phone gas sensor, air monitor

Furthermore, placement of power transmitters and sensor nodes in WSNs also play a critical role in the efficiency of the system [94, 95, 96]. To enhance directivity of RF transmissions, Shao et al. [97] proposed a beam-steered antenna array to direct its main beam toward energy harvesting units. By controlling the length of transmission line to each antenna unit in an array, the phase radiating difference between units created shift in the main beam. By this way, the harvesting unit remains fed with energy even it was misaligned with the source by 35°. Using the harvesting unit presented in [98] as a demonstration, within 1 min, this system was able to harvest 68.7 μJ at 0° and 13.6 μJ at 35° at a distance of 2 m from the beam-steered source antenna array.

Conclusion

This paper summarized the state-of-the-art of RF power harvesting technology in recent years. This technology will play a key role in replacing batteries in the near future. Some applications of RF power harvesting have been practically realized. A basic RF power-harvesting unit includes three main modules: the antenna, IMN, and voltage multiplier. The total efficiency of the system is dictated by the harmony in the integration of all the modules. The designs and principles of each module were also discussed in the paper.

The RF electromagnetic waves are harmless, abundant in space, and is able to penetrate through soft tissues. Those are properties that make RF electromagnetic waves an alternative source of energy to replace batteries in many applications. Particularly, RF power harvesting supports low-power medical and healthcare devices and facilitates the development of WSNs and IoT by providing mobility of use. Additionally, the progress in integrating RF power harvesting circuits into CMOS technology creates a completely wireless SoC.

Besides progressive accomplishment in recent years, there are still a variety of rooms to further optimize the RF power harvesting technology such as increasing operation range, reducing transmission loss, optimizing PCE, and minimizing system dimensions are the targets of RF power harvesting research. Furthermore, research focusing on harsh working environments for RF WPH such as implantation conditions or underwater zones is attracting much attention to extend the capabilities of this technology. A fine manufacturing and packing process with cost-effective production is necessary to make this technology mature.

In short, the RF WPH technology is gradually becoming a reality. Although this technology still faces many issues, overcoming these challenges can lead the power industry into a new era of clean and sustainable energy.

Declarations

Authors' contributions

LGT carried out literature search and wrote the manuscript. HKC and WTP reviewed/edited the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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Authors' Affiliations

(1)
Convergence Institute of Biomedical Engineering and Biomaterials, Seoul National University of Science and Technology, Seoul, South Korea
(2)
Department of Electrical and Information Engineering, Seoul National University of Science and Technology, Seoul, South Korea
(3)
Department of Mechanical and Automotive Engineering, Seoul National University of Science and Technology, Seoul, South Korea

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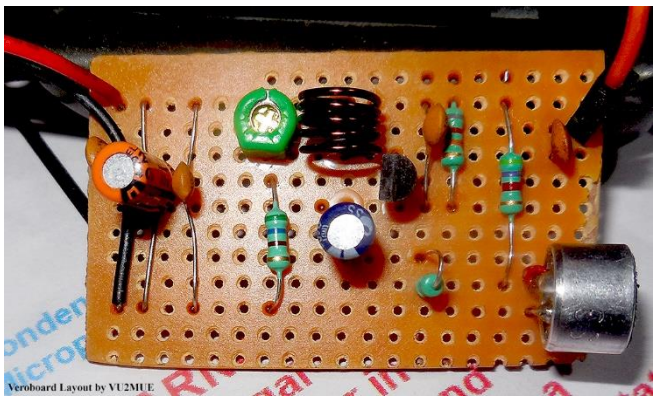
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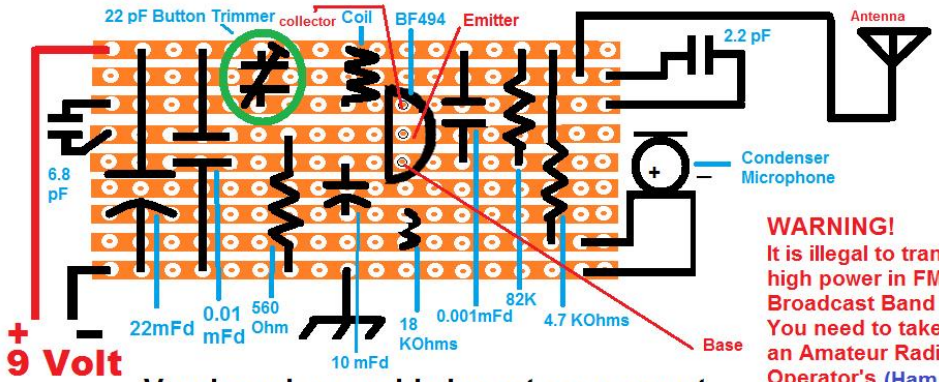
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FM Toy Transmitter Assembly Instructions



1. Component placement on the “veroboard” general purpose PCB.
2. Use 9 tracks of the veroboard as in the layout shown below:



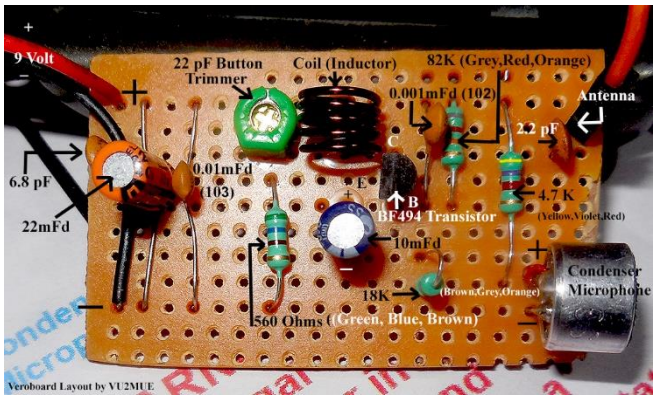
Veroboard assembly layout component placement of the FM Toy Transmitter (Top View ; Copper Side Down)

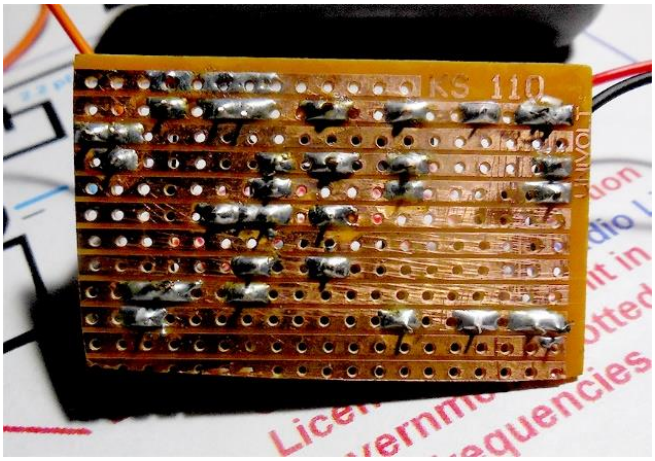
WARNING!
It is illegal to transmit with high power in FM Broadcast Band
You need to take an Amateur Radio Station Operator's (Ham Radio Licence) Licence to transmit in government allotted legal frequencies

This is a representative diagram only which is not into scale; apply your imagination to assemble it in a "close space" or "larger layout area" as per your soldering skill. Radio Frequency circuits assembled in closed space perform better as the Printed Circuit Board tracks also contribute to change in operational parameters

VU2MUE

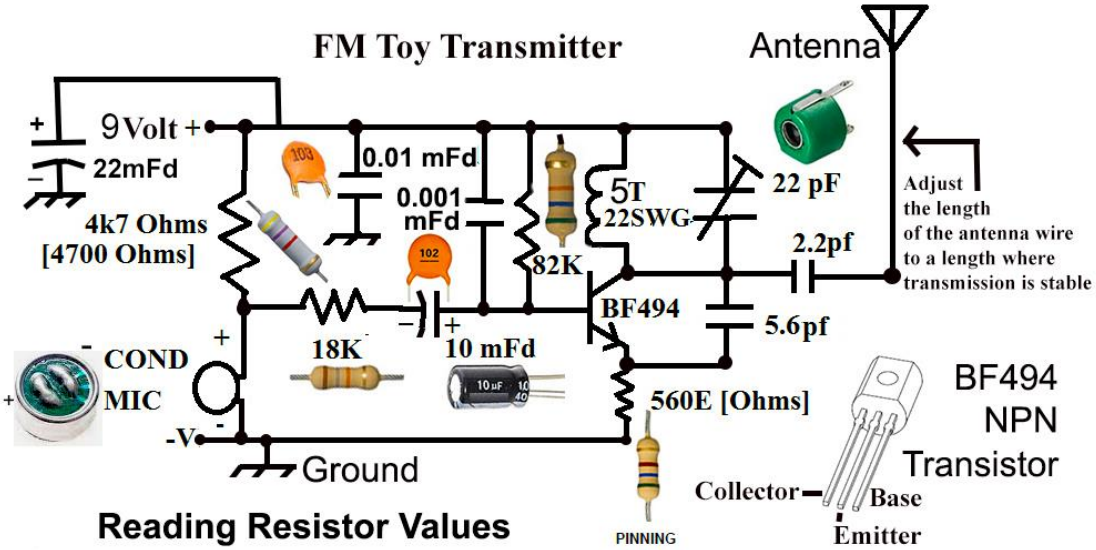
3. Component description



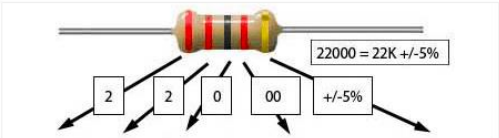


Bottom view after soldering

The circuit diagram



Reading Resistor Values

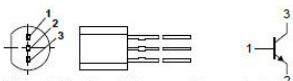


Band	1	2	3	4	5
Meaning	1st Digit	2nd Digit	3rd Digit	(No. of zeros)	Tolerance % (No band +/- 20%)
Silver				.00 (divide by 100)	+/-10%
Gold				.0 (divide by 10)	+/-5%
Black	0	0	0	No Zeros	
Brown	1	1	1	0	+/-1%
Red	2	2	2	00	+/-2%
Orange	3	3	3	,000	
Yellow	4	4	4	0,000	
Green	5	5	5	00,000	+/-0.5%
Blue	6	6	6	,000,000	+/-0.25%
Violet	7	7	7	0,000,000	+/-0.1%
Grey	8	8	8		+/-0.05%
White	9	9	9		

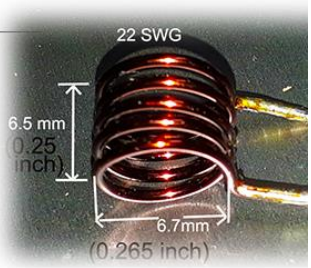
For better performance of the FM transmitter try to assemble it on a copper clad board instead of the veroboard provided with the kit, as RF circuits on higher frequencies (e.g. VHF) require adequate shielding

PINNING

PIN	DESCRIPTION
1	base
2	emitter
3	collector



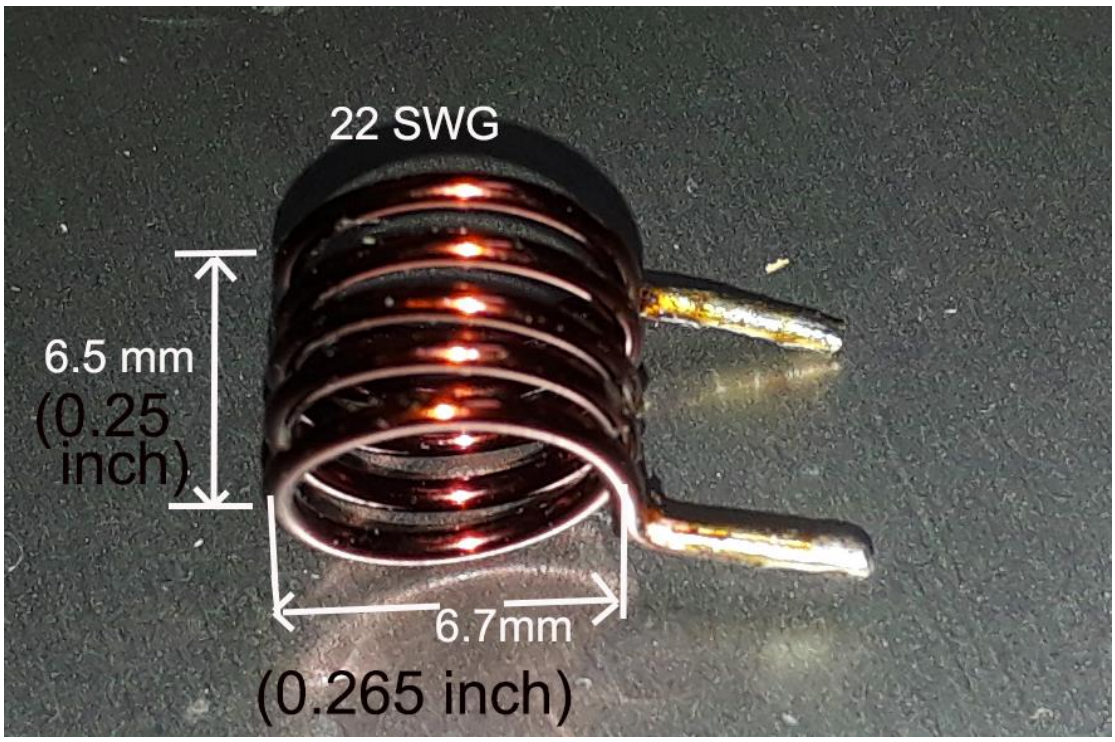
Simplified outline and symbol of NPN Transistor (TO-92 package)



Coil Specification:
Use 22 SWG copper wire
Coil diameter = 6.7mm (0.265 inch)
Coil length= 6.5mm (0.25 inch)
Number of turns = 5

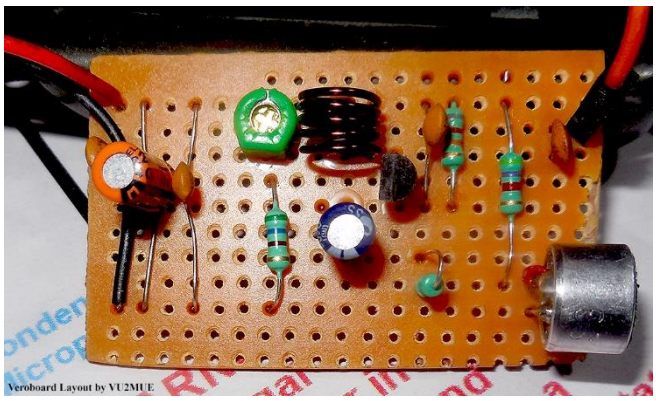
(Use a ballpoint refill of proper size to make the coil)

4. The “inductor” (coil) can be constructed using a ballpoint pen refill of proper size as described below by winding the copper wire (5 turns) provided with the kit. Remove the enamel insulation from the copper wire for soldering into the printed circuit board.

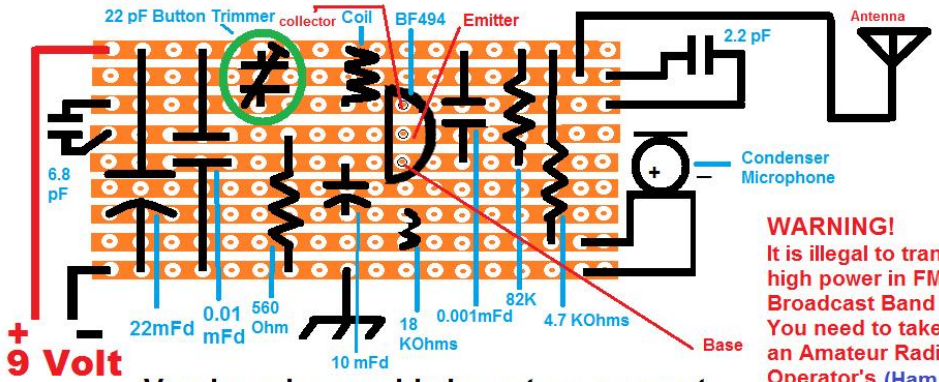


5. Solder a flexible wire (approx.. 1m in length) to the strip no. 2 of the veroboard where the 2.2 pF disc cereamic capacitor is soldered with its one end open. Any flexible conducting wire (with plastic insulation) used for electrical work can be used as an antenna. Hang it at an open space away from other objects for proper radiation.
6. The FM toy transmitter should be tuned to a frequency where no FM Broadcast station is transmitting. It transmits well near to 90 MHz (89-90 MHz). Turn the Green coloured Button Trimmer (Variable Capacitor) using a small screwdriver while keeping a FM Receiver tuned to 90 MHz. When tuned, the noise from the FM receiver would be squelched by the blank carrier transmission from the transmitter and there would not be any noise on the receiver’s speaker. Now play some song from any device by keeping it near to the FM transmitter microphone

FM Toy Transmitter Assembly Instructions



1. Component placement on the “veroboard” general purpose PCB.
2. Use 9 tracks of the veroboard as in the layout shown below:



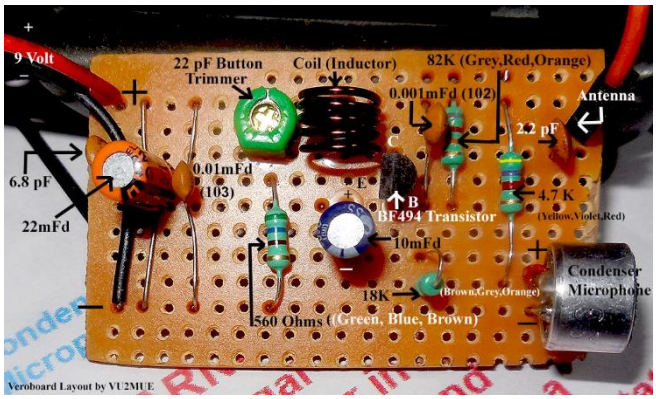
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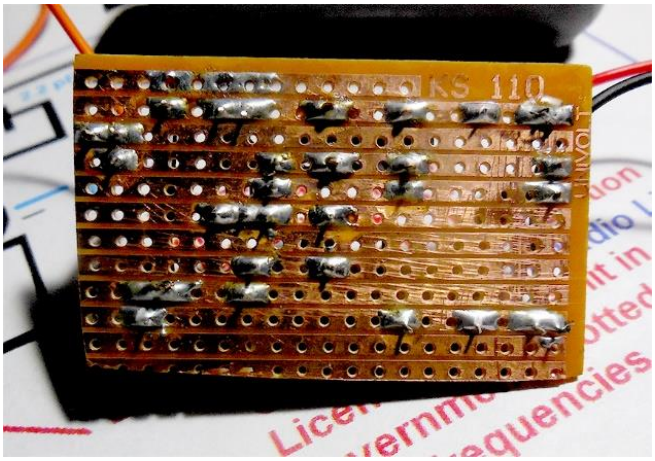
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VU2MUE

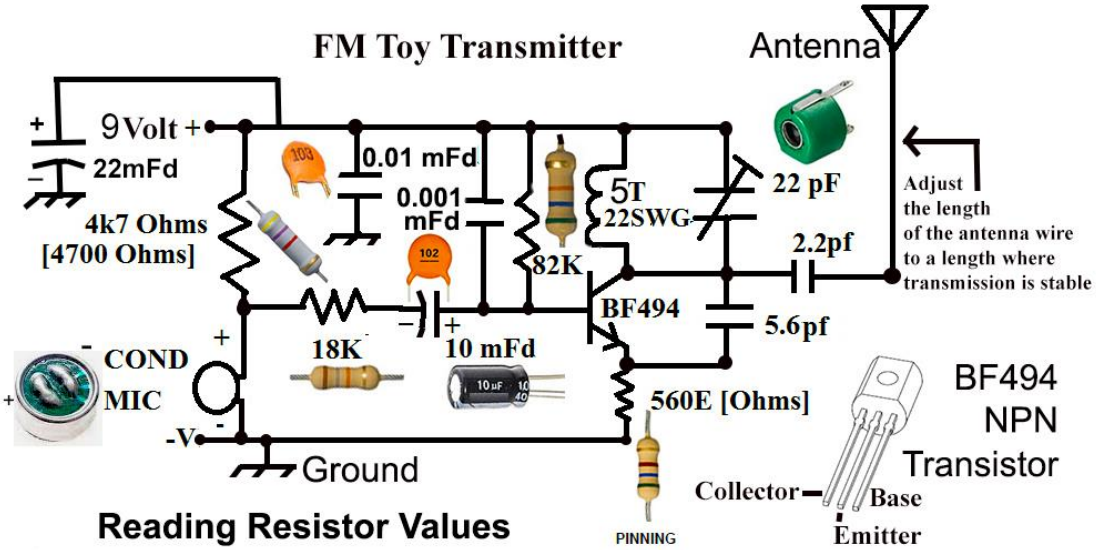
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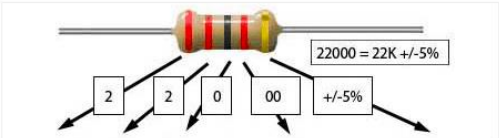


Bottom view after soldering

The circuit diagram



Reading Resistor Values

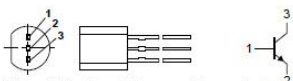


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Orange	3	3	3	,000	
Yellow	4	4	4	0,000	
Green	5	5	5	00,000	+/-0.5%
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Grey	8	8	8		+/-0.05%
White	9	9	9		

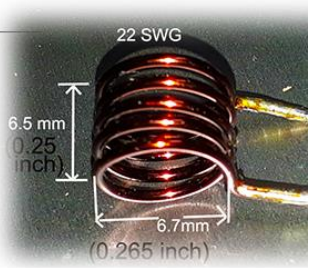
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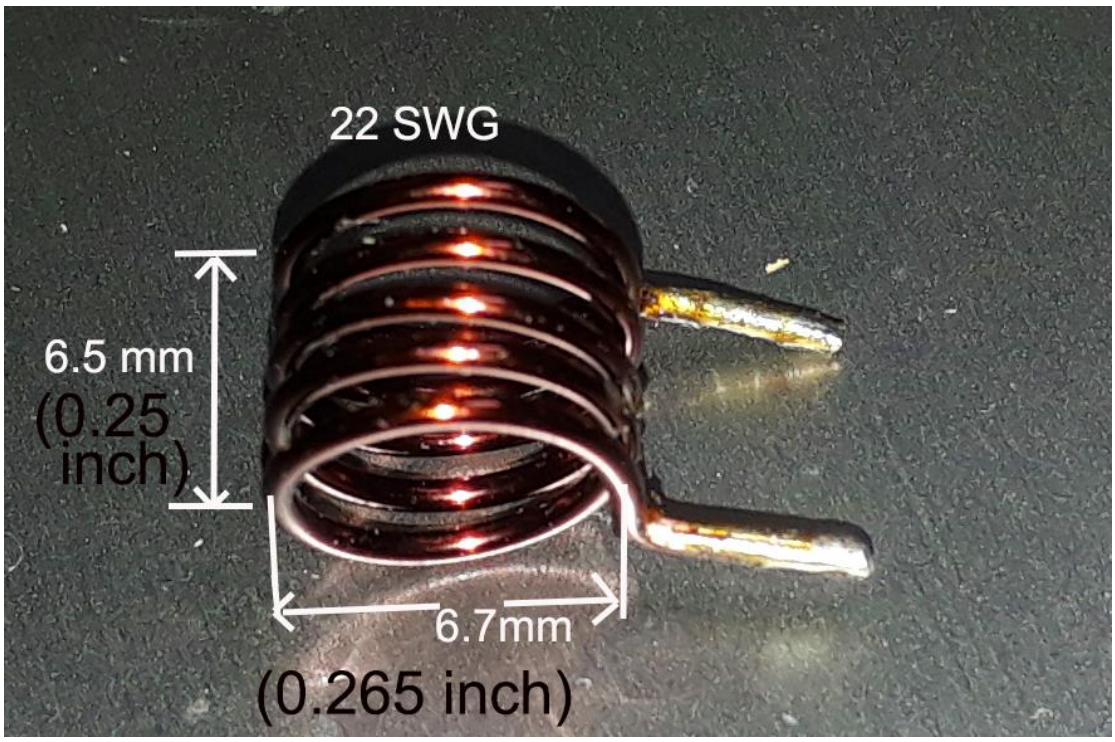
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A Homebrew 30 Meter Radio in a Weekend

Harold A. Smith—KE6TI harold.smith@gmail.com

Most weekends my wife and I try to do something together. One dreary weekend in January, though, my wife had brought a lot of work home, and was going to be busy both days. I was on my own. While I was waiting for some parts I'd ordered for the big project radio I'd been working on, I had been browsing my little technical library. I had picked up some ideas, so I decided to see if I could build a radio from scratch in a weekend.

Fortunately, I have a reasonably deep junk box. I have been building radios, and scrounging parts for radios, since dinosaurs ruled the earth and antennas were made of wood and stone. (Trust me, aluminum and copper are a great improvement.)

I decided to try for a thirty meter radio, because I had a crystal at 10.111 MHz, scrounged from a defunct satellite receiver. I built the transmitter first, because I thought it would be easier, and thus would give me more nearly instant gratification.

The circuit I used for the transmitter came from my trusty copy of *Solid State Design for the Radio Amateur*. It is the circuit that, I think, has come to be called the Little Joe, an excellent two stage design by W7ZOI.

I made a few changes from the SSD version. The result is shown in Figure 1. I wanted to use the crystal in a variable crystal oscillator (VXO), so I modified the oscillator for that. C2 and C5 are both 100 pF, larger than I would otherwise have used in those positions. Larger feedback caps seem to allow more tuning range in a VXO. I added a 15 µH molded choke and a variable cap that I estimate had a maximum capacitance of about 100 pF in series with the crystal. Those gave me tuning from about 10.107 down just to the lower edge of the band. Not a huge range, true, but better than being stuck on a single frequency.

I used an untuned transformer between the oscillator and the final, though I kept the same 9:1 turns ratio. I figured if it did not work I could tune it, but it seems to work just fine. Finally, I changed the output low pass filter to a 5-element one for more harmonic suppression.

I also used transistors that I had available in the junk box. The oscillator is a PN2222, though any similar transistor ought to work. For the final I used an obsolete National NSD102, a supply of which I found at a hamfest a few years ago. In the original version W7ZOI used a 2N3553, also obsolete, but possibly more obtainable, since it was made by more than one vendor. And there are many transistors that are still easily available that will work.

Finally, I used a Japanese PNP for the keying transistor, but a 2N2907, 2N3906, 2N4403 or MPS-A56 will work just as well. Note that, as built, the final is keyed and the oscillator runs all the time, which may or may not be optimum. It will certainly make it easy for the receiver to spot, but might overload it.

The transmitter worked when I first powered it up, putting out a clean-looking 1.5 watt sine wave into a 50 ohm dummy load. Figure 2 shows the finished product. As is the usual case, I used "ugly construction" to make the little rig. Total building time was under two hours, which left a big chunk of the weekend for a receiver.

The receiver, a direct conversion type, started with an idea gleaned from a presentation by Rev. George Dobbs, G3RJV, at FDIM 2005, and documented in the Proceedings. One of the circuits he mentioned was the two-diode frequency-doubling mixer, which is a circuit in which the local oscillator (LO) is injected at half the working frequency. The mixer then doubles the injection frequency. The advantage is that the LO does not run at the signal frequency, and is thus immune to pulling. I had seen the circuit before, but had never tried it. This seemed like the opportunity. Figure 3 is the resulting receiver schematic.

I built the LO first, a Clapp variable frequency oscillator (VFO) that covered 5.05 to 5.075 MHz, which when doubled

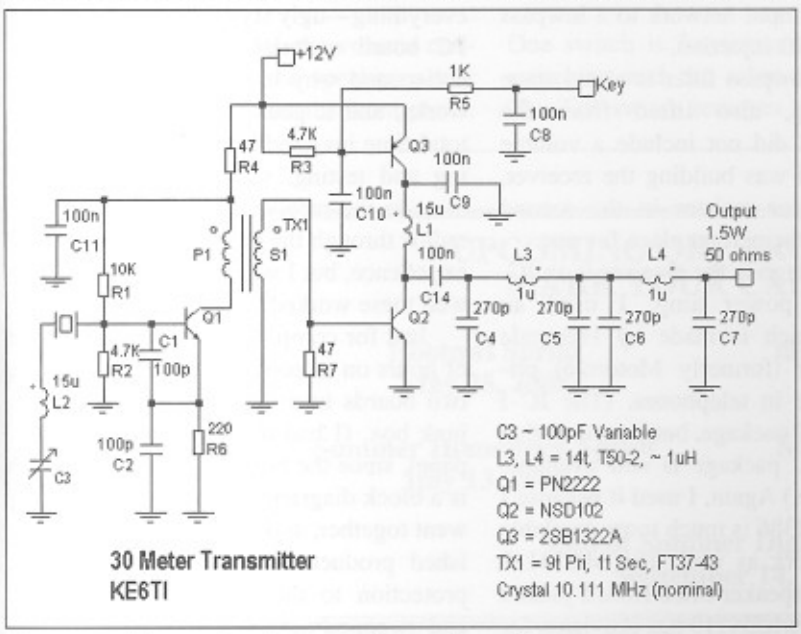


Figure 1—The weekend transmitter schematic.

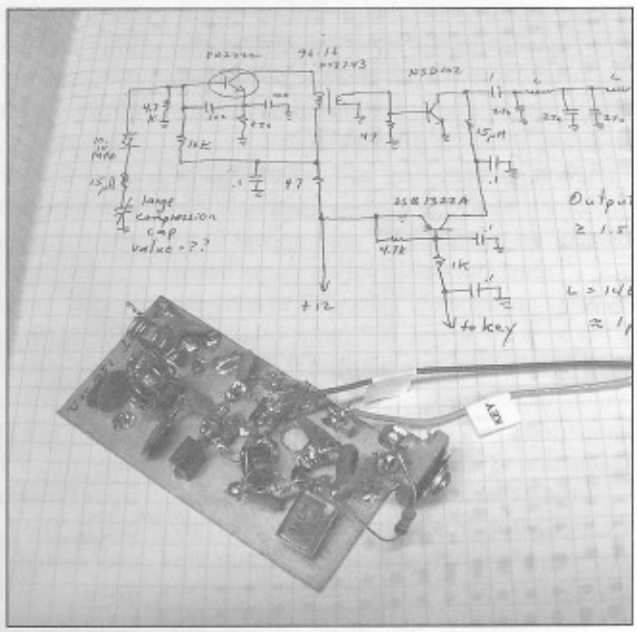


Figure 2—The transmitter board completed.

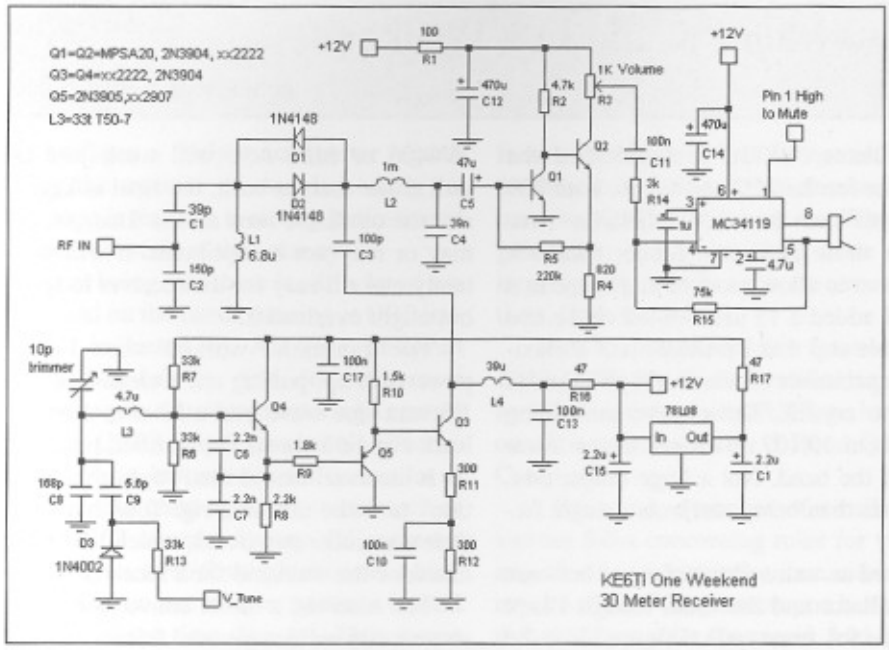


Figure 3—The weekend receiver schematic.

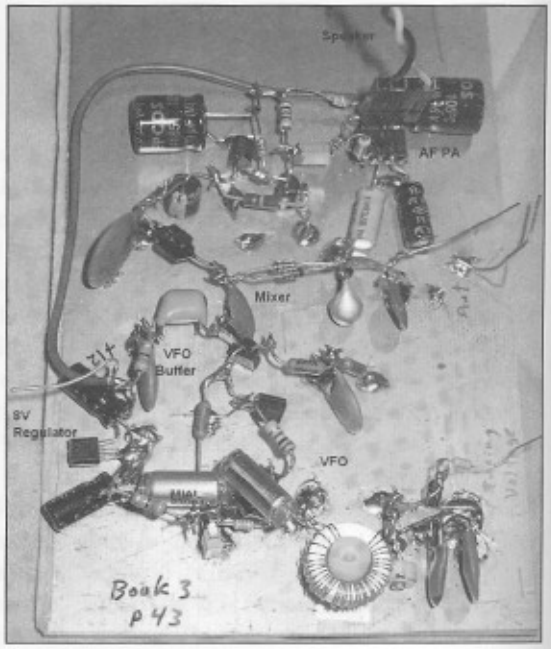


Figure 5—A view of the weekend receiver from another angle.



Figure 4—The weekend receiver completed.

just covered the 30 meter band. I used a pre-wound toroid from the junk box for the VFO's tank inductor, and tweaked the surrounding values to get the frequency range I wanted, compressing and expanding the inductor's windings a bit to fine tweak the range. The two 2200 pF caps appear to be polystyrene, but that's only a guess based on their appearance. I decided to tune the VFO with a voltage, and put a 1N4002 to work as a variable capacitance diode, which worked fine. (Had it not, I would have tried a real varactor, or perhaps the C-B junction of a bipolar transistor.)

I didn't measure the oscillator's stability, but it sat on a signal from one of my generators with no great pitch change for several minutes.

Theoretically, the mixer would not have pulled the VFO, but I am constitutionally incapable of building an unbuffered VFO. I added a simple, direct-connected two stage buffer, taking the output from the second stage's collector. I also added a small three terminal regulator to keep the VFO's supply voltage constant.

I used a single tuned circuit between the antenna input and the mixer, arranged for a bit of impedance step up. I didn't design that network; instead I simply scaled it to 30 meters from the one shown in the FDIM *Proceedings* article. The pair of diodes that comprise the mixer run from the top of the input network to a lowpass filter and the LO injection.

After the lowpass filter is a two stage audio preamp, also lifted from the *Proceedings*. I did not include a volume control when I was building the receiver, but the collector resistor in the second audio stage is the perfect place for one.

The final stage in the receiver is an IC-based audio power amp. I used an MC34119, which is made by Freescale Semiconductor (formerly Motorola) primarily for use in telephones. (The IC I used is in a DIP package, but it appears that only the SOIC package is still available from Freescale.) Again, I used it because I had it. The LM386 is much more available and should work as well. The MC34119 drives a small speaker lifted from a junked computer. The MC34119 has provision for muting by bringing pin 1 to the supply voltage, but I decided not to make use of that feature.

I did not really expect much from such a simple receiver, built so quickly and with so little analytical work on my part. But bench tests showed it could easily hear a 1 mV signal from my URM-25, and it had no trouble copying several 30 meter signals with no more antenna than a three-foot clip lead in my basement. I have not yet put it on my big outdoor antenna.

I built these two, transmitter and receiver, the way I build pretty much everything—ugly style, on a piece of scrap PC board material. See the pictures to understand why it is called 'ugly,' but it works, and it goes together quickly. The total time invested in these two, for building and testing, was about eight hours, most in the receiver. I have built a lot of radios through the years, so I have a bit of experience, but I was still surprised at how well these worked.

Just for completeness, I took a couple of hours on a second weekend and put the two boards into a cabinet I found in my junk box. (I had to come up with a back panel, since the box lacked one.) Figure 6 is a block diagram of how the whole thing went together, and Figure 7 shows the finished product. I added reverse polarity protection to the incoming power lead, and swapped out the mica trimmer in the transmitter for a small plastic variable. I

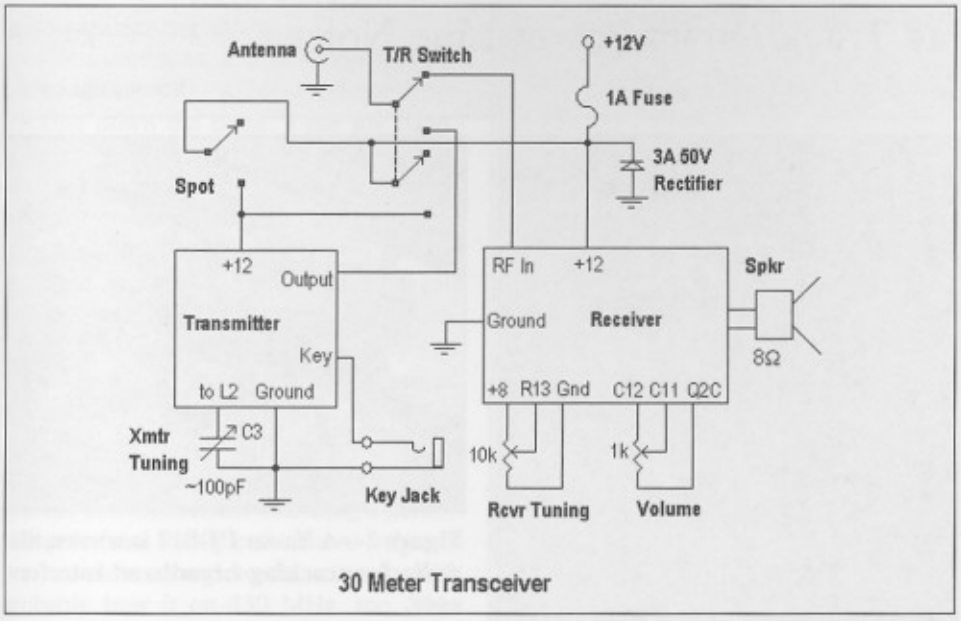


Figure 6—Transceiver interconnections.



Figure 7—The completed transceiver, installed in a "not so ugly" enclosure.

mounted tuning controls, the volume control (in place of R3), the speaker, a key jack and two switches on the front panel. One switch is for transmit/receive (T/R) switching and the other is for spotting. The T/R switch removes power from the transmitter when in receive, as well as switching the antenna from one board to the other. There is no provision for sidetone, which, in my station, comes from an outboard electronic keyer.

This is not really a construction article. I do not expect anyone to try to duplicate what I have done, but I wanted to show that building a radio is not necessarily a long, difficult project.

References:

1. http://www.qrp4u.de/index_en.html This is an interesting site generally. But see the "Some Useful Tables" section for the source of the transmitter's low pass filter.

2. FDIM 2005 *Proceedings*: 4. "Amateur Radio In Reduced Circumstances", Rev. George Dobbs, G3RJV

3. http://www.gqrp.com/ "A Short Guide to Harmonic Filters for QRP Transmitter Output." Rev. George Dobbs G3RJV. This is another table of low pass filters for QRP transmitters.

4. http://www.arrl.org/tis/info/pdf/9902044.pdf. Still more low pass filters.

5. http://www.aoc.nrao.edu/~pharden/hobby/_lpf_pa.pdf. This is an excellent tutorial on transmitter output filters.

6. http://www.agder.net/la8ak/c21.htm. LA8AK has loads of information in these pages. The link here goes to a page that includes information about the frequency doubling mixer I used in the receiver. (You'll find almost exactly the circuit I used labeled "Bad Construction." According to this site, I need to terminate the mixer better, but that is for later experimentation. For now, it seems to work well enough, at least on small signals.)

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AERIALS / ANTENNAS page 3

COPPER TUBE ANTENNA and Other Things by John G Hackett . . .

Hallicrafters Radio

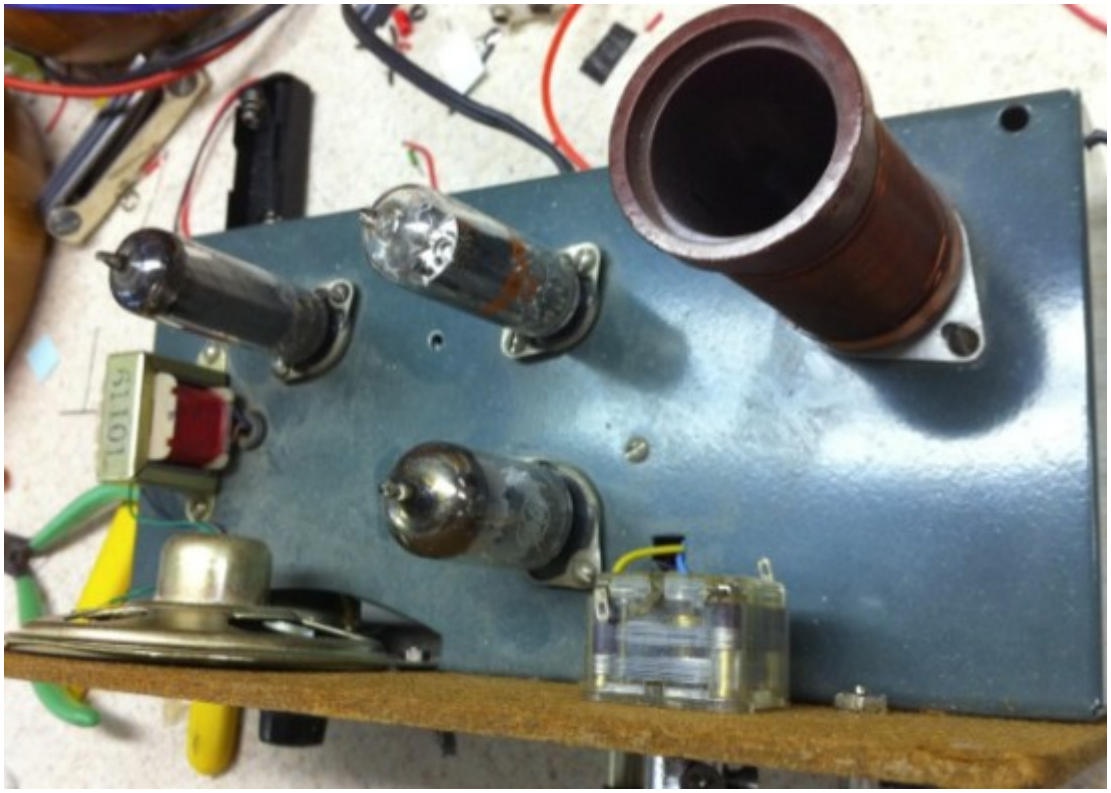
I have been dabbling in simple radio for the last 4-5 years, in dribs and drabs as time permits. Mostly I browse the internet looking for insights, but a ham radio friend of mine has been helping me. We did some troubleshooting on an All-American-Five AM/SW Hallicrafters radio from 1952 that my father gave me decades ago, using an RF generator and a nice scope that I've had for awhile. I replaced the tubes with known good ones, and the problem turned out to be that after the old wax caps had been replaced c1980, the coils hadn't been re-tuned. It took me days and days to finally figure that out, with the help of the good schematics that came with it. Even ret-uned the radio was marginal -- stations back then transmitted with more power than today. So I added a Ramsey SA7 broadband pre-amp kit (+16db) and that made a considerable difference!

The Regenerative Radio

My friend's basement is a debris field of old radio parts and gadgets, so he gave me this long-ago completed radio kit to tinker with. I thought I might renovate it into something classy, in a new cabinet. A nice wooden box perhaps?

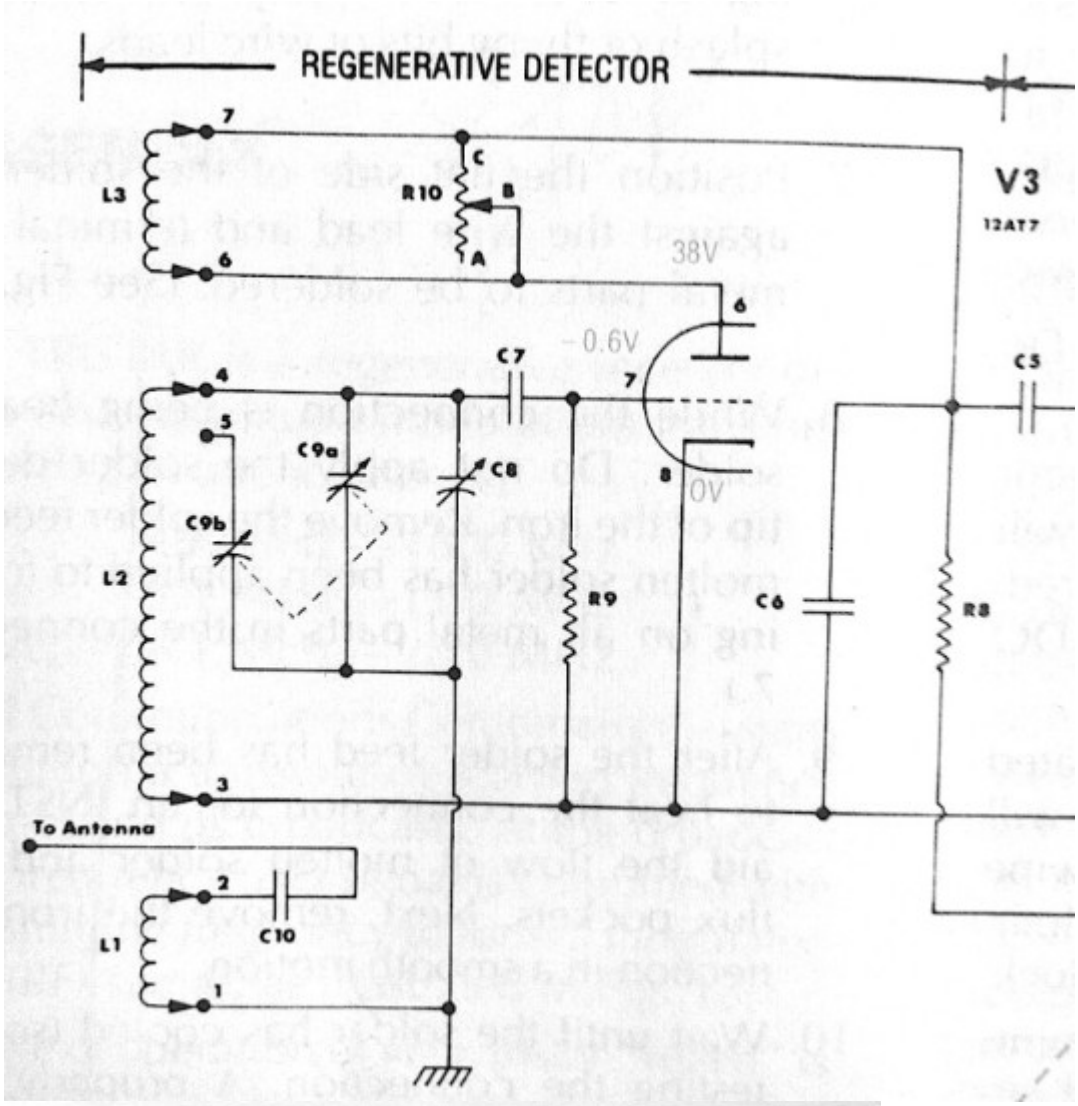


I started out by adding the vernier tuning dial and a 10-turn pot for regeneration (not band-spread as shown on the faceplate, which is fixed internally). These improvements made the tuning and regeneration ***much*** easier to control, but reception was just so-so with a temporary 10' wire antenna. The regeneration amplification is very touchy, but I can hit it so precisely now that I don't need to fiddle with it.



If any of your readers are curious, here is the regen detector circuit and description of function:

1975 Graymark 511 Tristar Regenerative radio:
R9 = 2.2M, R10=300 (now 10-turn), R8=47K,
C10=470 pF, C9 tuning=0-269 pF, C8 trimmer=0-20pF, C7=100pF, C6=.0047uF,
L1=L3=5 turns enameled wire on 1.125" core , L2=95 turns (no inductance values were given).



When a RF signal flows in the L1 winding, it creates a varying magnetic field around winding *L2 (tuning winding)*, which is positioned very close to L1. This causes a current to be induced into L2 by transformer action. L2 couples the signal to the control grid of tube V3. This signal is then detected and amplified, and causes a fluctuating dc current to flow in the plate circuit of V3. Winding *L3 (tickler winding)* is connected in the plate circuit, and is also positioned very close to L2. The fluctuating dc current in the plate circuit induces a current back into winding L2, that is in-step, *or* in-phase, with the current induced by L1. This condition is known as *regeneration*. This regenerated current is added to the original current and has the effect of increasing the strength of the RF signal to the grid of V3. If this regeneration current becomes too great, the circuit will go into *oscillation*, which will be heard in the speaker as a loud squeal. Potentiometer R10 is used to control this regneration current.

Copper Tube Antenna

Based upon the work done by http://www.am-dx.com/loopant.htm and others, I decided to experimentally build a copper tube antenna for DX-ing. The antenna needed to sit on a table and be rotatable by the simple expedient of grabbing its handle and maneuvering it around on its felt pads. This required that the width be limited, but height wasn't a problem... up to an 8' ceiling level from a table top, of course. I designed and tested the antenna *with* the radio piece by piece, trying every variation I could think of and observing the volume change of my strongest stations. I stopped at three loops because I didn't want to narrow the bandwidth of the antenna too much (AM-DX used *one* loop for this reason). My prior experience with a purchased tuned-loop antenna (30-50 loops?) showed wonderful gain but extremely narrow bandwidth -- I had to tune the All-American Radio to the station first by wire antenna, then switch in the loop and tune it, otherwise I could never align both tuners to the same station. I didn't want to deal with that complexity.

The toroid is the same Amidon FT-240-77 that AM-DX recommends. All of the solder joints were done with cleaned copper, flux, and silver solder. Note the copper tubes near the toroid do not touch, 4 loops of 8-gauge wire complete the connection. The secondary is 9 loops of 14-gauge wire. Everything was live-optimized *on and for this radio* -- the length of the copper, the number of loops, their tightness-looseness around the toroid, the number of loops of the primary and secondary, twisted-wire post-secondary (not a factor), the absence of a tuning capacitor at top, bottom, mid-loop, cross-ways, whatever -- it made no discernible difference. This antenna easily outperformed a 40' long wire antenna run along the ceiling of my basement in the same plane of the loops.

For display purposes ('antenna as art') I hand-sanded the 1/2" copper with 400-grit paper after final assembly and sprayed it with clear gloss acrylic so that it wouldn't tarnish. Three vertical oak dowels in the base support the copper. The oak cross pieces keep the copper tubes aligned, and short #6 stainless steel screws attach them into the back side of the copper.

Now the little regenerative radio strongly (allowing for its 1/2 watt audio amp) picks up 4-5 stations, and perhaps a half-dozen more passably well. A few more stations are very faint. Again, this is in my basement fully below ground level. The antenna appears to work equally well across the entire AM spectrum, but I have no way to measure that and stations are not equally distributed. I can't judge the noise level, but it seems reasonably quiet.



I'm going to dress up those loose secondary leads someday, but I haven't decided what would look best. Gray 5-way posts, probably.

I can't even guess at the impedance of this antenna, and I don't know how to measure it. I don't have a LCR meter, although I'd like one someday. I *am* confident that this antenna+radio system is mutually well-optimized, but I have no idea why it is. I have a Kenwood R-1000 radio I want to try out with it -- that's my next step, in fact. It has a signal strength meter and an attenuation switch which should give me a clue as to gain relative to a long wire.

I assembled a second Ramsey SA7 pre-amp kit this past weekend to try to improve reception. That's cheating, I know, but I was curious. Unfortunately this one is behaving oddly and I can't see anything amiss, 1 MHz in (confirmed by scope) is producing 70 MHz out. Weird. Ramsey hasn't replied to my inquiry and scope trace photos. Is 10mV an outrageously large test signal into a pre-amp? I was getting 200mV out.

A plea to readers : Overall impressions? Suggestions? Thoughts? Tests to perform? Magic words? Would an ATU be useful? Etc.? - email here

Thanks !

John Hackett
(April 2015)

Thank you for your email and fascinating descriptions. To be honest, I cannot add a lot to your copper tube antenna project as I have never made an antenna quite like that. I will say that you have made a very neat and impressive job!

I am quite surprised that it works so well, being an un-tuned device and so not resonant on the required frequency. I suppose that this would be compensated for if the pre-amp could be included. It would be an interesting solution.

I cannot be certain as to why you get 70MHz out for a 1MHz input, but maybe there is some parasitic / self-oscillation occurring? Perhaps some ferrite beads in strategic places could help - e.g. on input and output leads and on the semiconductor leads too. 10mV is a strong signal, but perhaps not as strong as you may expect to encounter, but nevertheless, maybe it is overloading the preamp circuit? You could try an attenuation pad. Perhaps some passband filtering between the aerial and the amp could help - but that's getting rather complex.

Thanks again for the super information - I hope someone will read the page and be able to offer us some additional comments!!

Best wishes, Mike.

Radio Stations & Memorabilia | **Loop & Frame Aerials** | **ATU's - Antenna Matching Units**

DXing & Short Wave | **Make A Signal Meter** | **Riding On A Radio Wave**

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My "King's Speech, Fireside Chat" Radio

A comprehensive story containing historical, educational, technical and biographical elements & opinions

by

John Fuhring

Introduction

Before you begin reading this story, I want you to know that what is presented here is more than simply an article, but rather a long story with certain autobiographical elements that I wrote for my own entertainment. I am presenting this story to you free and without commercials in the hope that you will be entertained by it. Please feel free to scroll down and skip around if you don't wish to read the entire story. The following several paragraphs are autobiographical, but I do not wish to impose my biography on you if you think it would be very boring, so you may skip ahead to the technology section if you wish to.



My beautiful Fairbanks Morse Model 58T1, circa 1936

I consider this to be one of the best expressions of the Art Deco styling so popular during this era.

The knob to the upper left is the Tone/BFO control. The below it is On/Off/Volume control and to the left of it is the Band Selector switch. The knob in the upper right directly across from the Tone/BFO knob is the Tuning control.

Judging from the size of this radio, its large speaker, the shortwave and other features, it is my opinion that this would have been a "parlor" radio and perhaps the main radio of an average family of 1936.

How and why I got my Fairbanks Morse

By high school, I was already a hopeless nerd. By then I had learned to love old radios and love fixing them up to make them work again. For a while, I even had a little business going fixing up old radios for friends of

mine. I had amassed a collection of wiring diagrams of many "modern" miniature tubes that I could substitute for the large old fashioned tubes in the old radios. Because the layout of old radios are generally so simple, I could do basic troubleshooting, put in new tubes and replace capacitors without schematic diagrams. It was a lot of fun and although it (obviously) had a deleterious effect on my social development, it did contribute to my later career in electronics.

After working on a few of these wonderful old radios for my friends, I wanted one of my own, so I started looking around and asked my parents to look around too. My folks found for me a 1936 Troy Radio (a beautiful radio I have recently rebuilt) and a friend of mom's dropped off a 1942 Philco portable radio I have written about elsewhere on this site. Neither of these radios was what I really wanted because they covered only the AM band and I wanted an old radio with shortwave. The Troy Radio was made bedroom or small apartment radio and the Philco was made after shortwave listening had lost most of its popularity. Of course, there was no eBay back then so I had to wait until an opportunity arrived by chance whereby I could pick up an old radio with shortwave.

Some time around 1960 I found a beautiful "Cathedral" style Philco "Baby Grand" radio in a back alley trash pick up and it had a shortwave band. I quickly dropped off my bicycle and then returned for the radio before the trash truck showed up. I took the radio home, cleaned it up and within a few days, had it working again. Doing some recent research based on my memory of the radio, I believe it was a 1934 model 18 with 8 tubes and a powerful "push-pull" audio stage. I remember that the sound coming out of its big electromagnet speaker was beautiful and it could really pull in shortwave stations loud and clear with just a short antenna wire. I also remember that it was limited to one low frequency shortwave band and it too turned out kind of useless.

I loved that radio, but when I returned from military service in 1969, I discovered that a lot of my old stuff was gone. My parents claimed that they had taken my stuff out to the garage for storage and that it had probably been stolen from there. I was extremely skeptical of that claim and I always suspected that they had simply given or thrown away stuff they considered old junk. Well, there was no help for it, my Philco Baby Grand was gone forever. Sure, I felt bad about it and I was angry with my parents for letting it be stolen (or more likely - given away), but by then I had moved on with my interests and I wouldn't rediscover the joys of old radios until several decades later after I had retired.

A year ago an old friend showed me a couple of old radios of his after I expressed an interest in them. After seeing them, I told him I could get them working again if he'd let me. I took them home, downloaded schematics off the Internet and that's when I rediscovered how much fun working on these old things is. Subsequently, I have fixed or put back together several old radios and stories regarding those projects are located elsewhere on my web site. Fixing up all these radios got me longing for my old Baby Grand again, but this time I wanted a slightly better radio with better short wave coverage.

First place I looked was eBay (where else?) and I found what I was looking for. I put in a few bids on some interesting radios, but most of them went for too much money so I'd usually drop out of the bidding. I did make an excellent deal on a Hallicrafters EC-1 sold for junk and parts only. Finally a Fairbanks Morse model 58 with a really beautiful dial, built during the right era (1936) and having exactly the shortwave coverage I wanted came up for bid. It too went for way too much money so I let it pass, but then a few weeks later I was notified that this same radio was up for bid again. Well, the second time it went up for bid, the price did not reach such an insane level and although I really didn't want to pay as much as I did, I bid enough to win the auction. Now that I have the radio and now it is working so beautifully, I don't grudge the amount I paid.

The seller was real good about sending it and it arrived from Tennessee ahead of schedule thanks to the efficiency of the US Postal Service. It was there on my porch waiting for me when I arrived home on a Friday afternoon well wrapped and in good condition. When I unpacked it, I was pleased that the wooden cabinet looked good, but not at all surprised that the electronics in the chassis had obviously not been touched in 50 years except to replace a power cord. I wasn't at all disappointed to find that the tuning mechanism was frozen and needed remounting on new rubber pads and that all the paper and electrolytic capacitors were in a horrible state, because I expected a radio this old would be this way.

So, I finally had one, a 1930s era radio with good shortwave coverage. It is hard to explain, but not having one of these radios was something I had left undone for five decades and now, all of a sudden, it became a big part of my fun to finally complete a project that had been neglected so long. Wouldn't it be great if all those other things in life that were never completed or done badly could be likewise revisited and brought to such a satisfying conclusion? Such is not in the natural order of things and I have to be satisfied with small triumphs.

How my Fairbanks Morse works.
Technology of a bygone era.

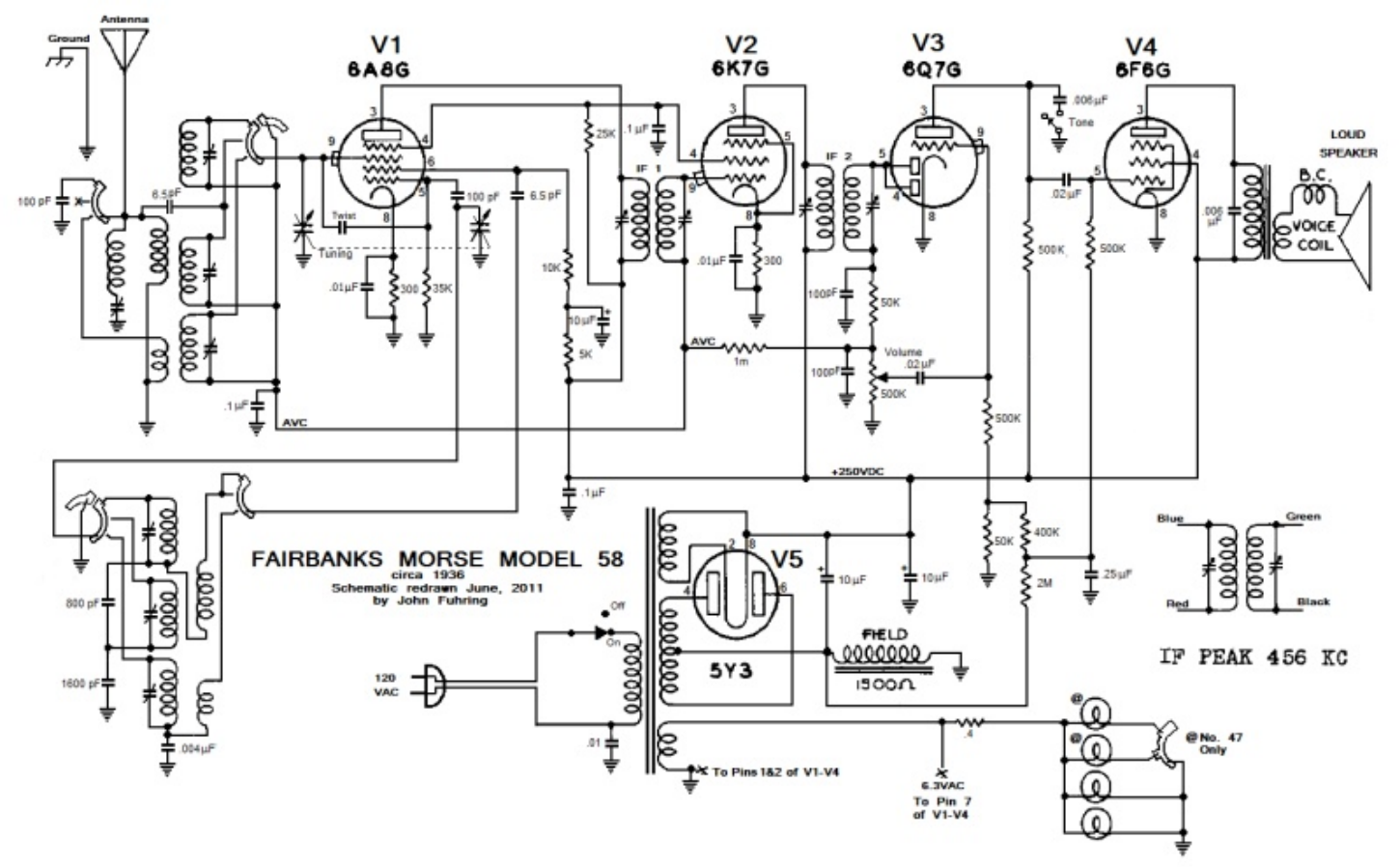
Warning

This next section is a digression and was composed for those who are technically inclined and who wish to know about how this and similar old radios work. If you do not know basic electronics, don't know what an oscillator is, you have no idea what the word superheterodyne means and you are a person who doesn't even want to know how your radio works, you might want to skip this section and go on down to where I talk about how I restored the insides of my radio and what parts I used.

The importance of a good schematic diagram

A good schematic is absolutely invaluable if you are to restore one of these radios. I will not even start a project until after I have obtained and redrawn the schematic for clarity and accuracy. That is exactly what I did for this project too. I downloaded a schematic from the fantastic source of modern knowledge, the Internet , and then used the Paint program to redraw it. The truth is, I generally spend more time redrawing and correcting my schematics than I do actually working on the radios. I have spent many hours on the schematic for this radio and if you want it for free, it is yours. All you have to do is drop me a line.

With the help of my newly created schematic, I had the confidence to pull out all the bad components all at once (something a beginner should never do). I cleaned the soot and dirt of 70 years off of them so I that could read their actual values and then make up a list of all the parts I'd need. I went down to the electronics store and for less than $15, I had all the replacement parts I needed. I used the schematic to properly place the new parts in the chassis, but not necessarily where the old parts had originally been. After all the parts were in, I checked and then double checked all the circuits to make sure their components were wired in correctly - again with the help of my good schematic. I always do this and by doing so, I am rewarded by having my radios play after the usual warm up period. I never have components smoke or overheat nor do I ever ruin anything by having the wrong thing in the wrong place.



Redrawn schematic of my 1936 Fairbanks Morse Model 58 radio.

Look at how simple this schematic is and how few tubes it uses (only 5). Many other more "prestigious " radios of this era used vastly more tubes (12 to 18). In many cases, the extra tubes were useless dummies or extra circuits of very dubious worth put in just to up the tube count. Like megapixals in today's cameras, somehow it got into the public's mind that the more tubes you had the better the radio would sound and perform. This was absolutely not the case and many of the more "affordable " radios, built by practical people for practical customers, had performance equaling or exceeding the more prestigious brands with their absurd tube counts. Not only were most of the extra circuits useless, there was much more to go wrong and at any one time, one or more of these superfluous tubes would likely be going "soft " and ruining the sound or reception. Fewer tubes meant less to go wrong and easier (and cheaper) to make right again. Recently I watched a period costume drama set in the mid 1930s and in this very brief scene the wealthy lord was complaining that their big expensive radio in the drawing room didn't bring in the stations or sound as good as the radio in the servant's quarters. I was very impressed that whoever wrote that tiny scene into the drama knew enough about the fine details of the era to have picked up on what must have been a common occurrence back then.

After redrawing the diagram (shown above) I was pleased to note that the radio radio's design is very familiar to me because I could see that it incorporates design features that would be used in almost all radios during the next 25 years. There were a couple of unusual design features I wasn't immediately familiar with, but they were easy to figure out once I had the schematic redrawn. Perhaps this isn't necessary, but here's a description of the main design features:

Main design features of the Fairbanks Morse Model 58 Radio

By today's standards, my radio is a rather conventional superheterodyne five tube radio that covers the AM broadcast band and two shortwave bands. As do all superheterodyne radios, my radio has antenna circuits that pick up very tiny electrical signals from the antenna, selects a particular signal from a station I want to listen to (called 'tuning') and connects that signal at the grid of a Mixer (or heterodyne) tube. Not to confuse you, but this mixer stage is also called the "First Detector" because this is where the signal is first processed by the radio. In the mixer section, the antenna signal is mixed (or heterodyned) with an oscillator signal called the Local Oscillator (LO) that is also tuned when I move the dial. This mixing of the two signals results in a third and lower frequency signal called the Intermediate Frequency (the IF). The IF signal is filtered and amplified by the IF amplifier. The signal from the IF amplifier is then detected by a tube called the Second Detector and the voice and music (audio) it contains is stripped off of it. Audio from this stage is amplified and then amplified again by the Power Amplifier until it is strong enough to drive the radio's large speaker. This superheterodyne system of receiving radio signals was invented by the brilliant radio engineer and inventor, Edwin Armstrong in 1917, but it was not widely used until much later and only after vacuum tube technology had advanced sufficiently to allow the circuits he invented to function in an ordinary radio.

All the tubes used in this radio had been developed and were made available to the market just a few months before the radio was manufactured and so this radio represented the very latest word in radio design for its time. These once high-tech tubes allowed for a radio that was simpler and better than radios which were just a year or two older and using less advanced tubes. I think it is fair to assume that my radio must have been on the drawing board sometime before its tubes were actually available on the market and while they were still in development because there is so little time between when my radio's tubes first came out and when my radio was manufactured.

Here then is a description of the tubes and the circuits my radio uses:

The first detector (or mixer or heterodyne) stage uses a 6A8 tube which is an early type of pentagrid converter tube. From this time on, most radios will be found using a pentagrid converter tube similar to the 6A8 for its first detector tube. The 6A8 tube was quite a sensation at the time it came out because it combined two functions in the same tube thus saving a lot of money and making for a simpler and better radio. Besides doing the mixing, it also functions as the local oscillator (the LO). The LO signal is created in one part of the tube, but in the same tube, the LO signal is mixed with the weak signal that comes from the antenna. This off the air or antenna signal has the music and voice we want to hear superimposed on its carrier (called a 'modulated carrier'). So, the tube is both an oscillator and a mixer. The result of that mixing is the creation of an intermediate frequency (IF) that is used in the next stage.

A little digression: The circuits associated with this first stage of my radio appeared unusual to me only because the Local Oscillator (or Heterodyne Oscillator) is configured as an Armstrong type oscillator with the +B voltage not applied to the "tickler coil" but through a 10 K resistor after being heavily filtered by a 8 mF capacitor.

I've never seen anybody do that before, but it works. A local oscillator circuit using pentagrid converter tubes are always configured as Hartley type oscillators not Armstrong oscillators, so this is really unusual. Now, isn't that just really interesting?

As mentioned, the next stage is the intermediate frequency (IF) stage. The IF stage consists of filter transformers and the IF amplifier tube (a 6K7). My radio's IF circuits are completely conventional and functionally identical to all radios that came later. The 6K7 tube was very special in its time because it is a variable transconductance tube (also called a remote cutoff, or a variable mu tube), as is the 6A8 tube. Those fancy terms mean that the amplification of one of these tubes can be controlled remotely by applying a negative voltage to the grid of the tube. As we will see in a minute, the negative voltage comes from the automatic volume control (AVC) circuit. Having an AVC in conjunction with these special tubes makes it possible to listen to a station who's signal is fading in and out without the volume changing a whole lot. It also enables you to tune around on the dial without blasting your eardrums if you tune across a loud and strong station.

The next tube, the 6Q7, is technically known as the "second detector" because it "detects" the voice or music that is on the IF signal. It also has circuits that generate the AVC mentioned above. Actually, the 6Q7 is two tubes in one. The diode section is the second detector and AVC portion of the tube and the other section is a very sensitive audio amplifier that takes the very weak voice and music from the detector stage and boosts it up so that it can be further amplified and be heard in the speaker. The 6Q7 is another early version of a type of tube that is found in almost all subsequent radios.

By the way, the diode section of this tube (the "second detector") is actually a Fleming Valve detector circuit that was developed in the early 1900s even before the days of the crystal radio. The Fleming Valve detector was so good at doing what it did, it was used in all later AM radios until tubes became obsolete.

As I just mentioned, the diode section of this tube is used to generate the negative automatic volume control (AVC) voltage. The way this AVC circuit is designed is very familiar to me because this is the famous circuit invented by a young Harold Wheeler in 1925 and patented by the Hazeltine corporation around 1932. When my radio was made, it wasn't a new circuit, but it was only then becoming popular because of the availability of the new tubes that could work with it.

Here's how the Hazeltine AVC circuit works: a Fleming Valve diode AM detector rectifys the carrier to produce a negative voltage in addition to producing voice and music. Strong AM carrier signals from a strong station will produce a large negative voltage while a weak carrier from a weak station will produce a very small negative voltage. If this negative voltage is placed on the grid of a variable transconductance tube (like the 6K7), a strong carrier will decrease the audio volume a whole lot while a weak carrier will decrease the audio volume by very little. This results in the sound level staying close to the same regardless of the strength of the signal. From about the time this radio was made onward, this simple, but very effective circuit was used in almost all radios.

I would like to repeat that the triode (right hand) section of the 6Q7 tube takes the very weak music and voice (audio) signal from the Fleming Valve diode detector stage and amplifies it to a usable level so it can be fed to the volume control. The way the triode is configured in my radio confused me at first because it is biased differently than anything I had ever seen before, but otherwise it is the same circuit that was used in all tube radios that followed my radio. Although the triode section greatly amplifies the sound, the signal is still not nearly strong enough to drive a speaker and so the audio signal first goes through a volume control and from there it is coupled to a power pentode audio amplifier tube (the 6F6) that raises it up to speaker level.

The 6F6 audio power amplifier tube is what is called a power pentode. This tube had been developed so that a single tube could provide enough power to drive a big speaker with plenty of volume. The earlier radios used lower power tubes and required three tubes arranged in what is known as "push-pull" (technically called "class AB2). With tubes like the 6F6, radios could be made much simpler, cheaper and better with just one tube in the audio output stage.

After 1937 the 6F6 would become obsolete as the famous 6L6 family of beam power tetrodes would come on the market and a lower power version, the 6V6, would completely replace the 6F6. By the way, it is my understanding that the 6L6 is still in production and the last (and most powerful) of this family, the 6KD6 is the tube I use as the power amplifier in my ham radio transmitter. For simplicity and low cost, radios such as my Fairbanks needs only one 6F6 (or 6V6) tube. An audio power amplifier that uses a single tube is rarely configured to produce more than 5 watts of audio power, but for really large console radios with more than one large speaker, multiple tubes were configured in the old "push-pull" arrangement (as mentioned earlier) for

dozens of watts of power. Nevertheless, for the smaller parlor radios working into a single high efficiency speaker, 3-5 watts is more than enough to fill a whole room with sound -- and loudly too.

Looking back, all these circuits seem very conventional, but at the time this radio was made, it had in it advanced circuits made possible only because of the recent availability of sophisticated, high-tech, high performance, multi-element tubes. The designer(s) of this radio took advantage of the fact that these new tubes could perform more than one function and they avoided making the radio overly complicated by using no more tubes than actually needed. At the same time, other manufacturer marketed more "prestigious" and "high-status" radios that had a separate tube for each function. These much more expensive radios had superfluously high tube counts and were marketed to an upscale customer base at a higher profit margin. If you can believe it, some of the upscale radios of this era had 15 to 18 tubes, most of which did nothing but cause trouble. Certainly, many of these upscale radios did sound marginally better and there were customers who demanded the absolute best sounding radio regardless of price. These were the people who could afford to regularly replace tubes and pay a radio technician to keep their sets working properly. However, to the ears of most people, these complex radios sounded very little better than the simpler radios. When you consider that both the simple and the complex radios were used to listen to the less than superlative audio quality that is typical of an AM broadcast, it isn't surprising that most people couldn't hear any real difference between these radios. Most people considered the simpler radios, such as my Fairbanks, to be an excellent compromise between good sound quality and cost and were therefore the best value for the money.

Fortunately, for the unknown person who first bought my radio, the designer(s) of my Fairbanks Morse decided to use the latest tube technology and by doing so, they made a simpler radio that not only had excellent performance and was easier to maintain, but it saved that unknown first customer a lot of money and thereby gave that customer a greater value for his/her money. By designing their radio simpler, cheaper and better than the more expensive radios, they also saved **ME** a lot of time, effort and expense when I restored my radio. In short, the designers of my radio back in 1935 were practicing the very best of what today we call **modernity**. This radio was a good example of the concept of modernity put into practice. I think it is very ironic that my simpler Fairbanks Morse radio is today (for me anyway) much more desirable to own than the more upscale radios of the same era.

The way this radio differs from later tube radios

For me, one of the things that is most unusual about this radio is the electromagnet that is used to generate a powerful magnetic field that operates the speaker and doubles as a choke coil to filter the hum out of the power supply. This was a very old fashioned arrangement and it was used because electrolytic filter capacitor technology had not been well developed and so those capacitors were huge and expensive. Back in those days, it was cheaper and better to use a big choke coil and to build the choke coil into the speaker where it could be hidden away. Of course, this would introduce hum into the speaker, but that could be overcome by using another unusual thing I'd never worked with before, a *hum bucking coil* (the B.C. coil shown in the schematic). A few years later, new capacitor and tube technology would make it possible to make a similar performing radio with a much simpler, lower voltage power supply.

Speaking of power supplys, my radio's power supply is not simple or low voltage. It produces 250 volts DC using a large power transformer and a full wave rectifier (the 5Y3 tube). Using an expensive transformer makes for a safe radio and therefore no back panel was needed to protect people from dangerous and painful electrical shocks. Later, with the elimination of the transformer and the development of tubes with high voltage filaments, the (in)famous *All American Five* (AAF) configuration was developed. These new AAF radios would be smaller, much cheaper to manufacture and much more affordable. However, cheapened up the way the were, they would not have the quality sound of the older radios. The worst thing about the newer "All American Five" radios was that they were and are much more dangerous than the older radios. I wonder how many people have been electrocuted by small transformerless radios they foolishly placed in their bathrooms or next to the kitchen sink?

By the way, 250 volts of direct current (DC) is exposed under the chassis of this radio where only a radio technician can possibly encounter it. As bad as it seems, this 250 volts is much, much safer than the 120 volts of alternating current (AC) that appears on the very chassis itself of the AAF radios. Thomas Edison noticed it back in the 1890s that AC voltages are about 10 times more dangerous than DC voltages and so, even if a radio technician should accidentally touch the 250 volts deep inside the underside of the radio, it would be painful, but not very dangerous. I'm certainly living proof of that because I can't tell you how many times I've been "bitten" by high voltage DC power supplies while working on tube radios.

Finally, the thing I found very different from anything I had ever worked on before was the way the 6F6 and 6Q7 tubes were biased. Usually the second detector's triode section is self biased with a high value grid resistor (like ten megohms) and the audio power tube is biased with a resistor and electrolytic capacitor in the cathode circuit. Well, in those days, electrolytic capacitors were big and expensive (as already noted) and since there was already a large negative voltage available at the choke coil, all they had to do was make up voltage dividers using standard (and cheap) resistors and they would have the voltages necessary to bias the tubes properly. Because of the way the original schematic was drawn, at first I couldn't quite figure out just what was going on, but after redrawing it, I could see and appreciate the simple, but clever way they biased those tubes.

As amazing as this 1930s technology is and how it seems so wonderful to me, the sad truth is that it now so terribly old fashioned and obsolete and I wonder how long it will be before there is nobody left who understands it anymore. The last of us vacuum tube dinosaurs will soon be extinct and then these old radios will truly be a thing of the past.

With the end of this technical digression, you might want to read about how I removed parts, put in new parts and got old frozen mechanisms working again.

Rebuilding the old radio
A mystery that was nearly a show-stopper

One thing that really threw me was the old fashioned way of assigning values to the resistors. This set uses very old fashioned resistors (and all of them are still good after all these years). The colors have faded and the old fashioned color scheme is such that I have found it pretty near impossible to tell what their values are supposed to be. What I really found confusing was how they were assigned values in the parts list. Ordinarily, a resistor that has 10,000 ohms of resistance is written as 10K, a resistor that has 1,000,000 ohms of resistance is written as 1M. In the old parts list of this radio, 10,000 is written as 10M and 1,000,000 is written as 1 megohm which, to me is exactly the same thing. Since resistors above one or two megohms are very rare (there is only one in this radio), when I saw resistors labeled as 500M and 60M and that just astounded me really threw me into a loop. Five hundred megohms!?! Sixty megohms!?! WHAT?? THAT JUST CAN'T BE!! This had me worried. I sure hoped that none of the resistors were bad, because in today's world, it would be virtually impossible to find replacement resistors with values like that. In fact, I have no meters that can measure anywhere near that high so it would be impossible to test them.

Before I began working on the radio or even take it out of the wooden cabinet, I began formulating a plan to redesign all the circuits to operate with "normal" values of resistance and replace all the old resistors with their impossibly high resistance. Thank the gods that it dawned on me that maybe the famous Rider company had made a big mistake and had really meant to write 'K' for 'M.' In the parts list, when I scratched out 'M' and wrote in 'K', all the circuits started to make sense. When I opened up the chassis and took direct measurements of the resistors with my ohmmeter, sure enough, they were Kilohm and not Megohms. What a relief, to know that my radio used ordinary resistors after all. On doing a little research (thank you Internet) I discovered that in the really old days of radio, M (as in Roman Numerals for 1,000) was used to indicate 1,000. Who would have thought it, but when you think of it, today we write the year 2011 as MMXI. We don't write today's year as KKXI, so perhaps I should have known better and not have scared myself as I had.

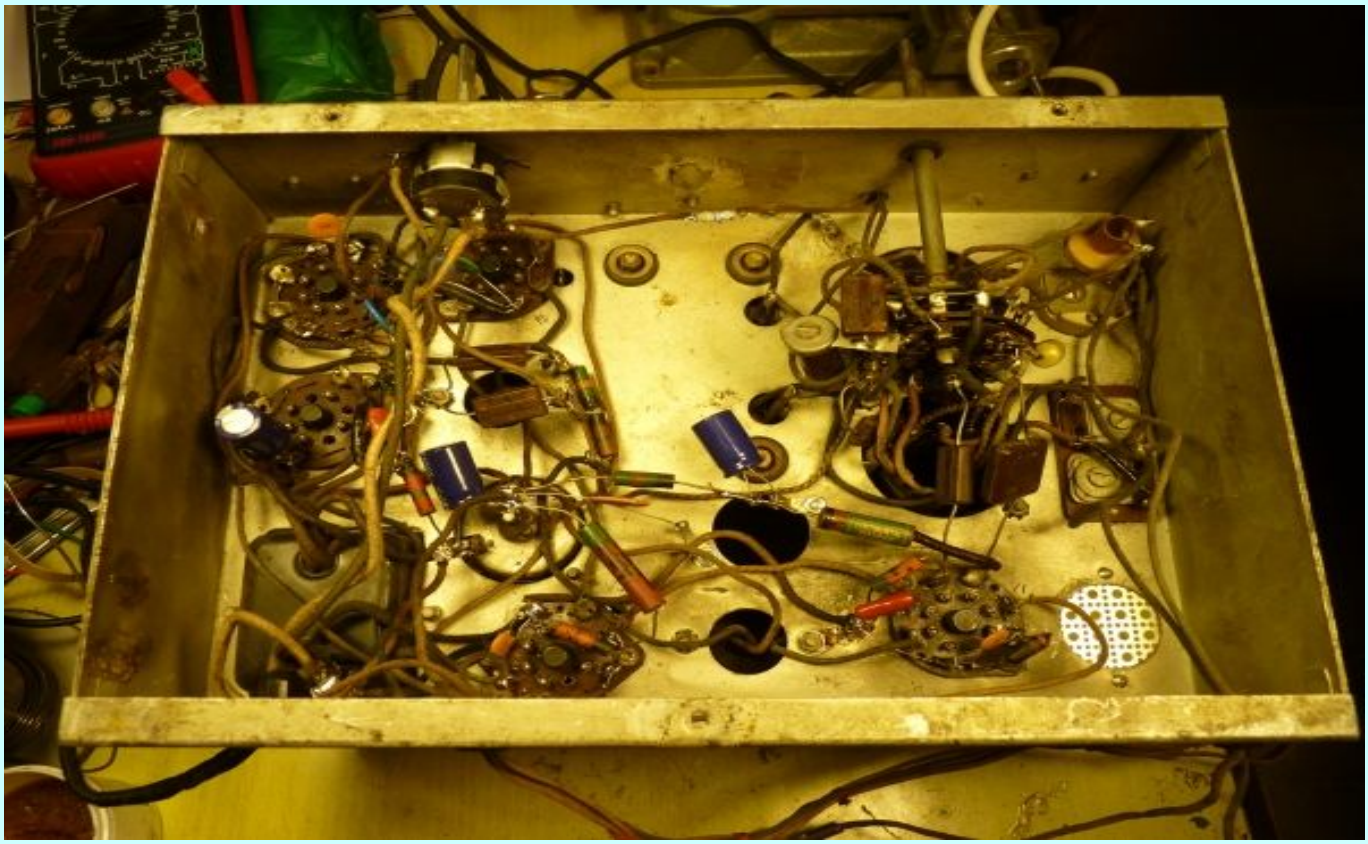
What a lot of time I wasted pondering this foolish little mystery, but I am so glad that I finally figured this out because I was just about to start yanking out and replacing resistors and that would have lead to a real disaster. I shudder to think how many hours I would have spent trying to recalculate values for voltage dividers, bias resistors, anode resistors and such things as those.

Horrible old parts I ruthlessly yanked out

Well, on the following Monday evening after the radio arrived and after I had obtained a schematic diagram for this radio, I took the chassis and the large, heavy old speaker out of the cabinet. Once out of the cabinet, I started to pull a pile of horrible looking old parts out of the chassis.



Horrible old parts I pulled out of the radio.
I had no idea what the lamps were, so I replaced them
with lamps I knew wouldn't put another burn mark on the dial.



With the large old parts stripped out and the tiny new parts put in, the chassis looks bare.
One of the genius of using tubes is that there are so few components that are needed to support them.

With the exception of the paper/wax and electrolytic capacitors, all the original components are as good as the day they were manufactured.

My town's Electronics Parts Supermart didn't open until the following Tuesday, so that morning there I was with a shopping list consisting of the ten ceramic and mylar capacitors and three 10 MFD, 350 volt electrolytics I'd need. I bought a pile of new parts much smaller than the pile I had removed. I soldered the new parts into the chassis that evening and, nerd that I am, I had a very entertaining evening doing that and watching it all come together.

The few parts I actually needed to make the radio work again

As it turned out, the seven 75 year old silver-mica capacitors were still in excellent condition so I left them alone. It has been my experience that silver mica capacitors never need replacement. Of course, the trimmers and the air variable capacitors were all as good as the day they were made and all the original resistors were good too (as they almost always are), so actually I had to replace only a dozen or so small parts. Everything I needed to spend on this radio came to less than $20. Not withstanding how little they cost, the ceramic and mylar capacitors that I put in this radio are far, far superior to the old paper/wax capacitors and they should last forever. With the exception of the electrolytic capacitors and the tubes, I figure that this radio should still be playing 100 years from now. Hopefully, the old radio will still be a cherished antique while what was once me is long forgotten and reduced to mere dust.

Clues to the repair history

While I was at it and while I had the guts of the radio exposed, I looked for clues regarding the repair history of this radio. By looking at the various levels of workmanship and especially noting the style of replacement parts they used at various times, I could tell that this radio had undergone major repairs on at least three different occasions and one final attempt was made recently. First, there was evidence that an electrolytic capacitor was replaced, probably in the late 1930s when those types were a little smaller than original, but still quite large. Next, it appeared that two more electrolytics and at least one paper-wax capacitor were replaced in the early to mid 1940s. Judging from the type of potentiometer that was used, it appears that the volume control was replaced in the late1950s. It also appears that the power amplifier tube was replaced by a slim "modern" one probably at that time too. Finally a modern "antique style" power cord was very inexpertly installed not too long ago in a futile attempt to get the set working again, but by that time the tuning mechanism was frozen and all the capacitors were too far gone to have allowed the radio to function anyway and so I'm sure whoever did the work realized he was over his head and just sold the radio as-is.

Final steps necessary to get the radio working after more than 50 years

By Wednesday I had the frozen tuning mechanism freed up, the tuning deck remounted on new rubber grommets and the whole dial mechanism working again. Another thing that was nearly a show-stopper was the fact that the very special belt that operates the dial mechanism had rotted away. I tried making up a belt out of multiple sections of heavy string, and it did work -- sort of, but I really needed a new drive belt for the dial mechanism. Wouldn't you know it, the Internet came to my rescue again. After searching around a bit, I found a company that makes drive belts for all old radios. I sent off for one and a few days later I had a belt made of a high-tech material that should last forever and with it installed, the operation of my dial is silky smooth.

I cleaned up 70 years of grime inside and outside the cabinet and chassis and, if I may say so, the beautiful dial of this old radio is ever so much more beautiful now that you can see it thorough the fogged up window.



his old radio has one of the most interesting and beautiful Art Deco dial mechanisms. The outer dials show the broadcast band (on the bottom) the first shortwave band (in green above the broadcast band) and the upper shortwave band (in red on the very top). The large slim pointer covers both hemicircles and one or the other ends of the pointer indicates what frequency you are tuned to. The very interesting inner dial rotates around and around and around as you tune so that you can keep track of exactly where you would point the dials if you wanted to return to a station again. The whole mechanism is on a precision gear reduction so that it is quite easy to tune in stations even on shortwave without using a separate fine tuning control.

What is really cool about this dial is the way it lights up. When the broadcast band is selected, both hemicircles and the center of the dial lights up in its beautiful colors. When shortwave band 1 is selected, the lower hemicircle and the center lights up, but when shortwave band 2 is selected, the upper hemicircle and the center lights up. It makes for a very interesting, colorful and beautiful effect. By the way, the knob on the upper left is the tone control and it works surprisingly well, but I am thinking of replacing it with a three position switch that would allow me to add and control a beat frequency oscillator (BFO) circuit so that single sideband (SSB) and Morse Code amateur radio broadcasts can be listened to --it would be very easy to do and it wouldn't effect the looks in any way.

Since writing that, I have indeed added a modern BFO and it turned out to be an excellent idea that works splendidly. From the outside, you can not tell this radio has a BFO and the inside of the radio is almost unchanged, but having it has opened up a whole new way of listening to short wave broadcasts.

On Wednesday afternoon after I had all the electrical, mechanical and cleanup work done, I plugged in the radio. As always, I had compared the schematic diagram with every circuit in the radio making double and triple

sure that I had everything installed correctly and that everything was as it should be. I turned on the radio for the first time in maybe 50 years or more with all the confidence that comes with having done all my homework and after a short warm-up, I could hear a normal quiet hiss, but no hum,and nothing smoked. I then turned the dial to the first AM station that I came to and and a beautiful, mellow sound came out of the speaker - probably for the first time in 50 or more years. I wasn't expecting all the old tubes to function, but they did, and perfectly. I then connected the antenna lead to one of my outside antennas and that evening I listened to shortwave broadcasts from all over the world.

Outside wire antennas

By the way, it is my firm opinion that this radio was most likely targeted for sale to rural customers and people who were familiar with the Fairbanks Morse name. Fairbanks Morse was a major supplier of rugged, reliable and affordable agricultural machinery and radios marketed by them would naturally appeal to farming people. Living in the country, far from broadcast towers, a rural customer needed a radio that could receive broadcasts from long distances and therefore the Fairbanks Morse company did not bother to include a built-in loop antenna, which is useful mostly in urban areas. To receive both the AM broadcast band and the two short wave bands, this radio has always needed some kind of external antenna and, in fact, farm houses of that era generally had long, high wire antennas just for this reason. For local AM reception, a short 1 or 2 foot piece of wire is all that is necessary, but for long ranges, a radio of this sort really shines when you connect up a long antenna that is 30 feet or more and the longer and higher you make it, the better.

Now, where was I?

To my utter amazement, I found that all the tuned circuits in the RF and IF stages were still in perfect alignment even after 74 years and there was no adjustments I needed to make to improve the radio's already excellent performance. The dial calibration is right on the money and the tuning is sharp and sensitive with more than enough volume even on the weakest signal. There is nothing more I need to do with this radio except perhaps to restore the cabinet to look a little newer. But perhaps I should leave it alone because the first thing that everybody says who have seen my radio say is that it looks like a modern reproduction and not like they would expect an old radio to look.

What have I done this time?

I think I done a bad thing George. Oh my, I may have desecrated my old radio by doing something an antique purist should never do. Yes, I added a modern BFO to my old radio. This is another technical discussion and if you are not interested in such things as BFO's, you might want to skip this section.

Of course, this radio was designed for home entertainment and to listen to AM broadcasts from all over the world. It was designed before single side band (SSB) broadcasts and not meant to receive Morse Code so it did not have a beat frequency oscillator (BFO). Only military and certain specialized amateur radios had BFOs back in those days, but today there isn't much left of the once glorious programming that used to be on short wave and so a BFO is now a very desirable thing to have. I greatly expanded the usefulness of my beautiful old Fairbanks Morse by adding a very simple, very inexpensive, but very effective BFO to my radio and I did it without altering the fine appearance of the radio or even its basic wiring.

One of my my unbreakable rules when restoring this radio was that no modification would be visible, I would not, under any circumstances, desecrate the beauty or originality of the old radio except in ways that could not be seen and the modification could be removed in an instant and without rewiring the radio. In all regards, my BFO module satisfies these restrictions. What's really neat about what I've done is that I didn't touch any of the existing circuits in any real way and what I've added is so unobtrusive, you'd never know it was in there. To remove the BFO, all I'd have to do is cut out two new wires and simply lift the little module out. Within a minute or so, the radio would be exactly as it had been originally designed. I wouldn't even have to replace the new tone control switch I put in, but I will keep the old one just in case I want to put the radio back exactly as it was.

I installed the device as an experiment to see if having a BFO would enhance the operation and enjoyment of the radio and in that, I think I have succeeded very well. I can truthfully say that the BFO works splendidly and I'm pleased to be able to listen to single side band (SSB) Morse Code broadcasts that were always there, but until now, unavailable. With this little device I'm able to expand the usefulness of the old radio beyond the dwindling AM broadcasts it was limited to.

The BFO circuit is built on a tiny perf board and mounted next to the IF tube using the screw and nut that fastens down the second IF transformer. The DC voltage to power the unit is from pin 8 of the 6K7 IF tube. Pin 8 is the cathode circuit and develops about three volts across its bias resistor. Because the BFO module draws

so little current (about a half a milliamp), it effects the bias of the tube very little when the BFO is turned on and not at all when the BFO is turned off.

To provide on/off control of the BFO, I replaced the two position tone control switch with a three position switch. The first position is like before with the audio at full range, the second position is as before giving more bass to the sound, but the third position disables the automatic volume control (the AVC) and turns on the BFO module. Looking at the front of the radio, you'd never know it had a BFO and until you place the tone control all the way over, it works and sounds just as before.

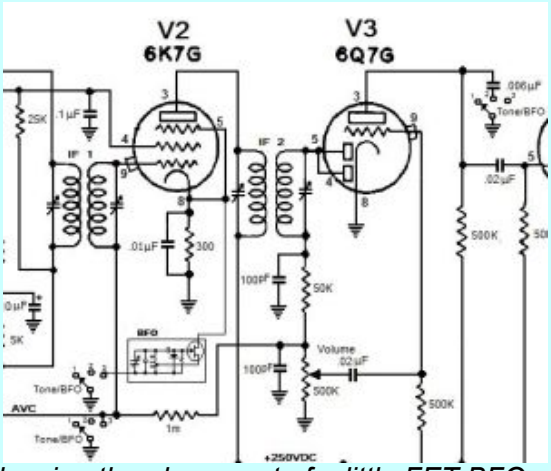
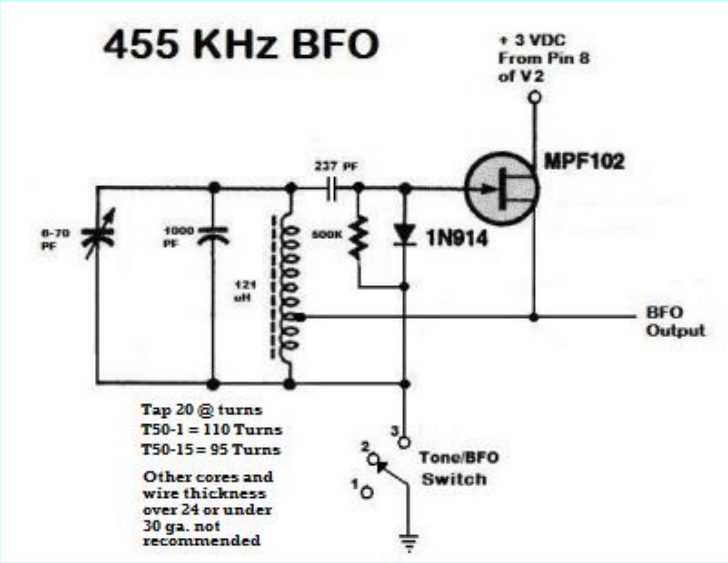


Diagram showing the placement of a little FET BFO module and the three ganged Tone/BFO Control switchs. The first two positions control the tone, the third position turns on the BFO.



Here's a detailed schematic drawing of the BFO I built and installed in my radio.

As simple as this circuit is, it puts out a very clean signal and I can not detect any harmonics or "birdies" that are so common in other transistor oscillators. I have used this very circuit in my S-120 and my S-38b receivers and it works splendidly in all of them, opening up single side band broadcasts that were once impossible to listen to.

The coil was wound on a T50-1 (blue) toroid form using 24 gauge magnet wire. Total turns was about 110 with a tap after 20 turns with a overall length of wire a bit less than 2 meters. Of course, you can use other cores (like the -15 @ 95 turns) and smaller gauge wire and you can adjust the circuit values any way you wish as long as you get a 455 KHz output. The 237 PF coupling capacitor can be anything from 50 to 500 PF, the resistor can be anything

from 500K to 1M, but be absolutely sure to use a 1N914 or other "high speed diode" in the gate circuit. Silver mica caps are nice, but I used ceramics and they work just fine.

It really helps to have a frequency counter when making and adjusting one of these little modules, but it may be adjusted simply by tuning in a moderately strong AM station, turn on the module and then adjust the trimmer cap until you hear a whistle. Adjust the whistle for the lowest tone (zero beat) and that's all there is to it.

This little module produces a clean 455 KHz carrier that mixes with SSB and CW and turns them into intelligible signals surprisingly well. Because it is tied to the cathode of the IF tube, there is no need to couple the output signal to any other part of the radio and so the wiring and installation is simplicity itself requiring nothing more than the module, three wires and a new wafer switch. The new wafer switch has two extra circuits the old switch didn't have. When the BFO is turned on, one of the circuits disables the AVC line so that the BFO's signal doesn't cause the gain of the mixer and IF to be reduced and the other circuit provides a ground (or return path) to turn on the module. That's all I had to do.

Normally I do things very conventionally and the conventional way of wiring in a BFO is to take its output and couple it to the grid of an amplifier so that it will mix with a signal. Connecting the drain of the FET to the cathode of the IF tube is so utterly simple, but something that hadn't occurred to me before and I didn't know if it would work very well. In fact, this way of powering the module and injecting the BFO signal at the same time has just amazed me by how well it seems to work. Last night I listened to Single Side Band broadcasts on 80 meters and all the signals, ranging from very strong to very weak, sounded good, really good. To tell the truth, I am extremely pleased with this little modification and I consider it a positive improvement to the usefulness of the old radio.

Yes, the shortwave bands are only a shadow of what they once were, but with this BFO, much more is suddenly made available to listen to on shortwave. If you have one of these wonderful old radios, you might consider adding one of these circuits. Nobody will ever know you have put a BFO in there just by looking and the radio will work and sound exactly the same on AM, but by doing so, you will have a more useful radio. Of course, listening to most hams talk is about as much fun as watching paint dry, so you will have to decide if adding a little BFO is really your "cup of tea" or not. If you do decide you want to add a BFO to your old radio and you need more advice than what's here, drop me a line and maybe I can help.

Conclusion
The life and times of Depression Era radios

I'd like to say something about the fascination people had with listening to shortwave from the period of the early 1930s to about the end of World War Two. Listening to programs on shortwave from coast to coast, Hawaii and all the foreign countries was all the rage during that time. These were the days before television, CNN, MSNBC and the Internet so the radio was an important way for people to keep in touch with what was happening in the world and enabled people to find affordable entertainment on a daily basis. Every country in the world wanted its point of view known and every company wanted its products advertised and there were a lot of listeners out there, so everyone produced entertainment, news and propaganda programs that just filled the airwaves. Whatever time of the day or night, there was something on the broadcast band and usually some shortwave band was open too. With so many stations to listen to, a person could stay entertained and informed for just the price of electricity and a new tube now and again.

I should mention though that these radios were all hand wired and by today's standards, extremely expensive. My guess is that a new radio, such as my Fairbanks Morse, sold for the equivalent of maybe $1,000 to $1,500 in the mid 1930s, maybe more. These were a major purchase (next to a house and car) and so most people had only one (and room for only one) radio back then. Having a beautiful looking radio (with such a nice dial too!), a radio that sounded so nice and could tune in the whole world, must have been a great source of pride, in addition to its obvious entertainment value. I can only imagine how excited, pleased and proud the person was when he or she first took this radio to their home and plugged it in for the first time. I'll bet they invited the whole neighborhood in to listen to it.

The voice of President Roosevelt must have sounded many, many times in the very speaker I'm listening to

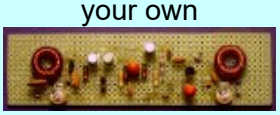
and the electrical undulations of his voice must have modulated the electron stream of many of the very tubes that are still in this radio as he gave his comforting and intimate "Fireside Chats." I can just imagine the whole family sitting around such a radio at night listening to this or an exciting drama, comedy show or a news broadcast of some important event - like a King's Speech - while during the day the radio would fill the house with the latest big band and jazz music or a baseball game while informing everybody within earshot of the advantages of Palmolive Soap and Wrigley's Gum and how lives are ruined forever by not using Listerine for their bad breath and the efficaciousness of Doctor Vornoff's Monkey Gland Treatment and how if you drink Ovaltine before going to bed, it will help you sleep and you will wake up **GAY** in the morning and how more doctors smoke Camel cigarettes than any other brand.

There are many beautiful old radios that date from this era, but in my opinion, my radio has one of the most beautiful dials of any of those radios. I think that only the Zenith radios had dials as pretty as mine. You may have noticed that I'm calling my radio "The King's Speech Radio" because it is altogether possible that the abdication of King Edward ("I can't be King without the support of the woman I love") was listened to, via BBC shortwave, the December following my radio's manufacture and then later little brother Bertie's famous speech was also listened to, again via BBC shortwave, three years later on September 1939 as Britain began the second great war with Germany. I think I'm going to add "Fireside Chat" to the name of my radio because it is almost certain it was used to listen to those too. I love these old radios for their beauty, their interesting technology and the fact that they are an important and key artifact of our culture and civilization from a very important time in the history of the world and my country. I don't know if my parents and grand parents owned this particular model of radio back in the 1930s, but whatever they owned, it was something very similar.

THE END

Having arrived this far, obviously you have a superior attention span and reading ability that far exceeds that of the
majority of web users. I highly value the opinion of people such as yourself, so I ask you to briefly tell me:
Did you enjoy this article or did it suck?
Please visit my guest book and tell me.

If you have an antique AM radio and you need something decent to listen to, perhaps you should buy or build your own



Low Power AM transmitter

Recently I found and restored a 1938 Crosley Super 8 radio that was from a posponed repair job 50 years ago



Please go to my Crolsey Radio Story

There is another story of how I recently restored a 1930s that my parents gave me when I was a kid



Please go to my Troy Radio Story

For a simplified, but more in depth explanation of how this and similar radios work, you might be interested in



An essay on the Armstrong Superheterodyne Radio Principle

I have a lot of other old radio stories on my website



Please select another radio article

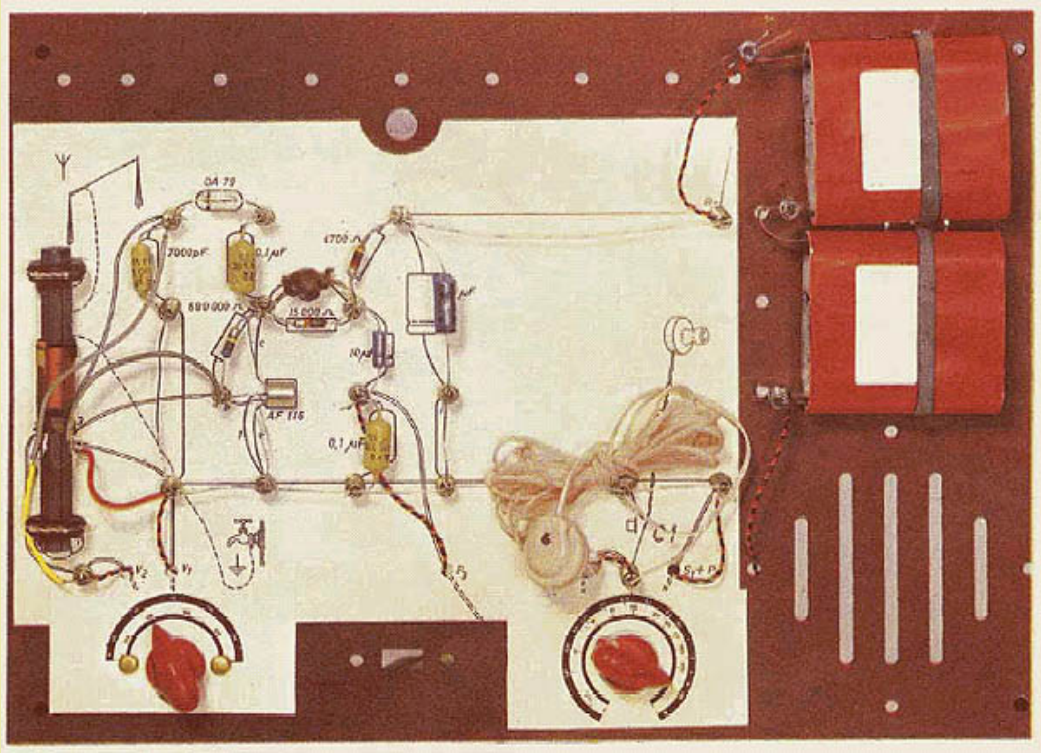
For other stories and things,
Please check out my Home Page

OLD PROJECTS

(1963-1982)

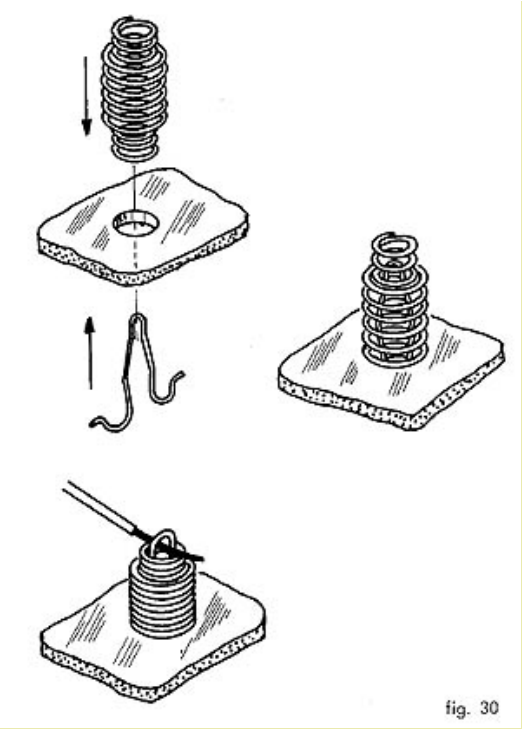
KLIK HIER VOOR DE NEDERLANDSE VERSIE

This story is about the beginning of the radio hobby!



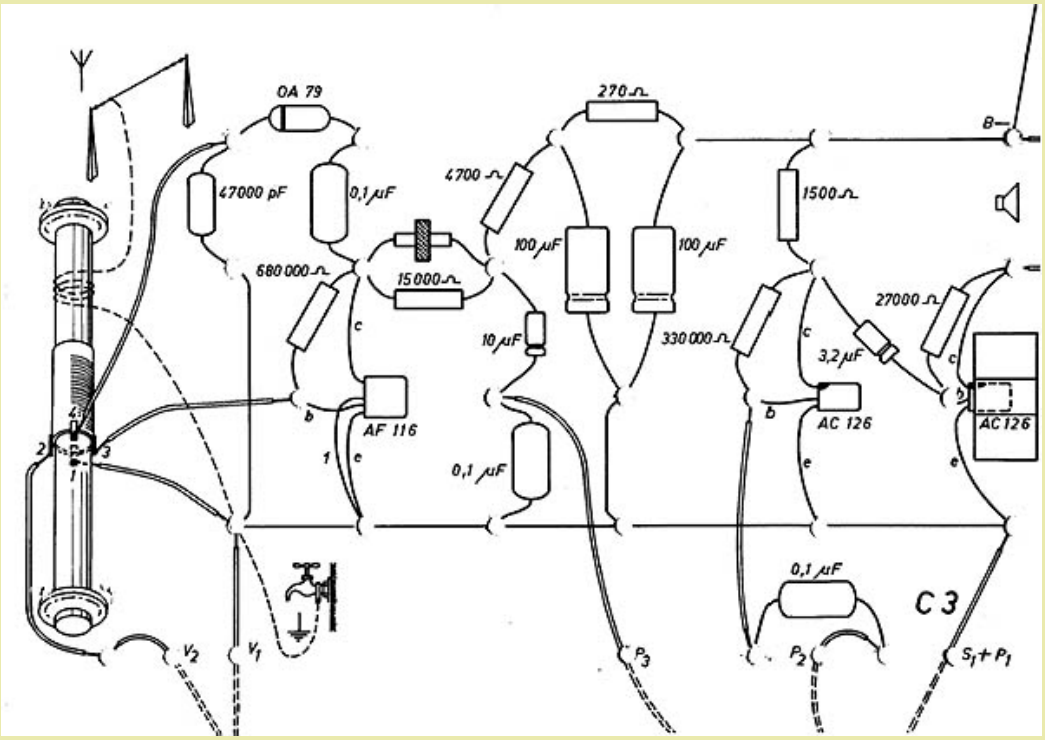
The radio hobby really started with this Philips EE8-EE20 construction kit!

EE8-EE20 construction kit
It started with the well known Philips EE8-EE20 construction kit for all kinds of electronic projects. It was approximately in 1963, when I was 10 years old. This construction kit was sold during the years 1963-1966. It worked with a system with springs on a piece of wood with holes.



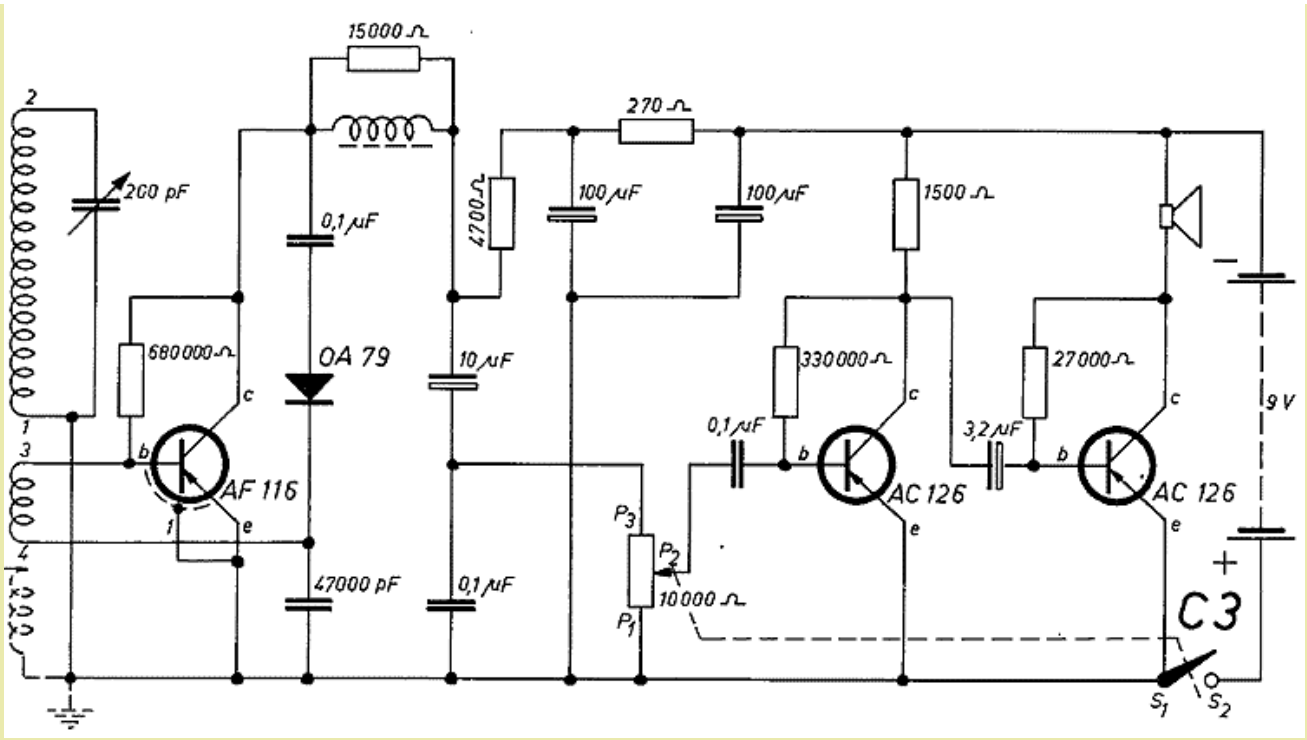
It worked with a system with springs on a piece of wood with holes.

The radio project was my most favourite project of this construction kit!



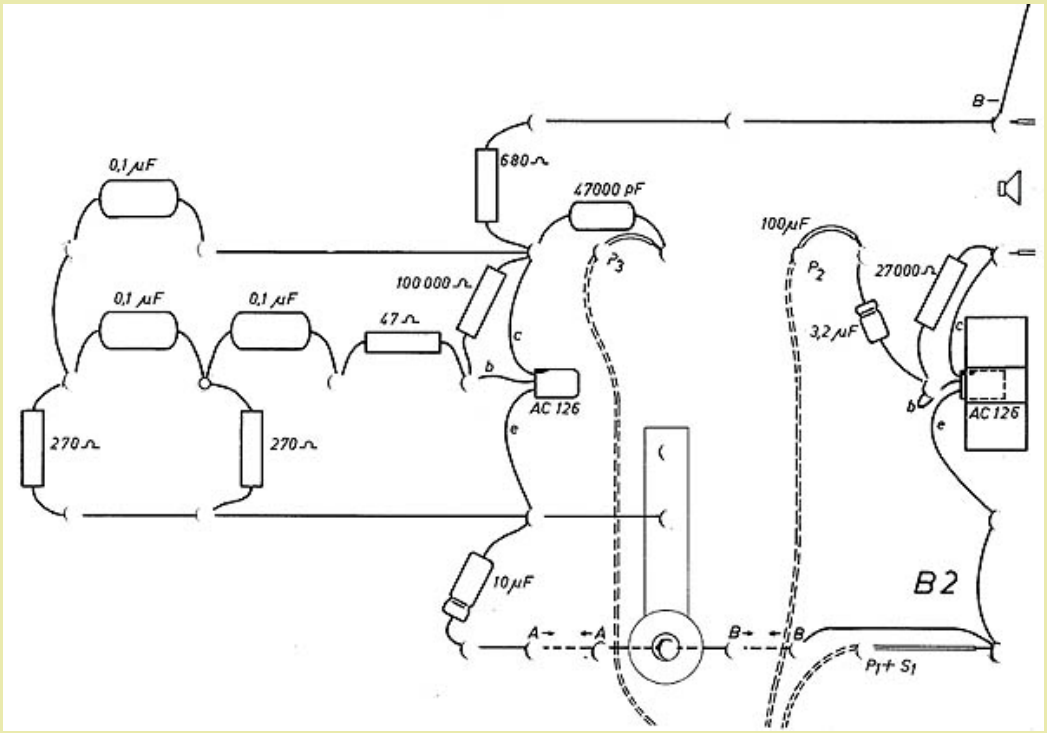
The radio project was my most favourite project of this construction kit !

This radio is a so called reflex circuit. The AF116 does not only amplify the RF signal, but also the detected audio signal. The diode detector with an OA79 does only work because a germanium diode does have a considerable leakage resistance. Detection performance is quite dependent on the leakage resistance of this diode. The loudspeaker is a 150 ohm type.



The diagram. The diode detector can only work with a germanium diode because of the required leakage resistance that such a diode has.

With an own wounded coil, it was possible to receive the coast stations and ships. The radio virus did never go away anymore! Also the morse code generator with key was very interesting! Quite soon I did practice much with the morse code and could already send all the characters!



The morse code generator with the simple key.

I did get a soldering iron and the "SUPPLEMENT" radio was made.
I did get a soldering iron and the SUPPLEMENT radio from the book "boys radio" was made. This was also a reflex receiver and it had the famous 402 coil. My portable regenerative receivers that I built 30 years later were based on this diagram! It was possible to receiver coast stations and shortwave stations when shortening a part of the 402 coil.

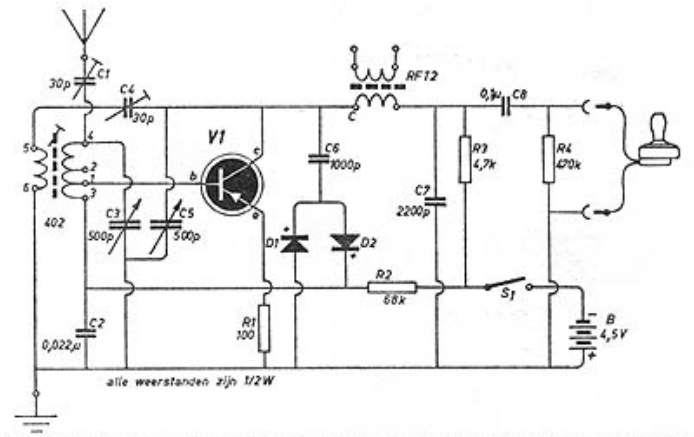


Fig. 1. SCHAKELING EN ONDERDELENLIJST

C1-4	= 30 pF luchttrimmer	R4	= 470 kΩ - ½ W (Vitrohm)
C2	= 0,022 µF papier (Facon)	RFT2	= r.f. transformator (Amroh)
C3	= 500 pF afstemcondensator	V1	= transistor SO1
C5	= ca. 300 pF terugkoppel-condensator	D1-2	= germaniumdiode b.v. OA81, OA85
C6	= 1000 pF papier (Facon)	S1	= enkelpolige schakelaar aan/uit
C7	= 2200 pF papier (Facon)		1 Uniframe UF 052
R1	= 100 Ω - ½ W (Vitrohm)		1 Uniframe UF 053
R2	= 68 kΩ - ½ W (Vitrohm)		1 Uniframe UF 054
R3	= 4700 Ω - ½ W (Vitrohm)		2 bevestigingshaugels voor bevestiging van C3 en C5

The supplement receiver was the first soldering project. It worked with a kind of blind rivets that you had to hit in the holes of a pertinax board with a hammer. The electronic parts were soldered in the blind rivets.

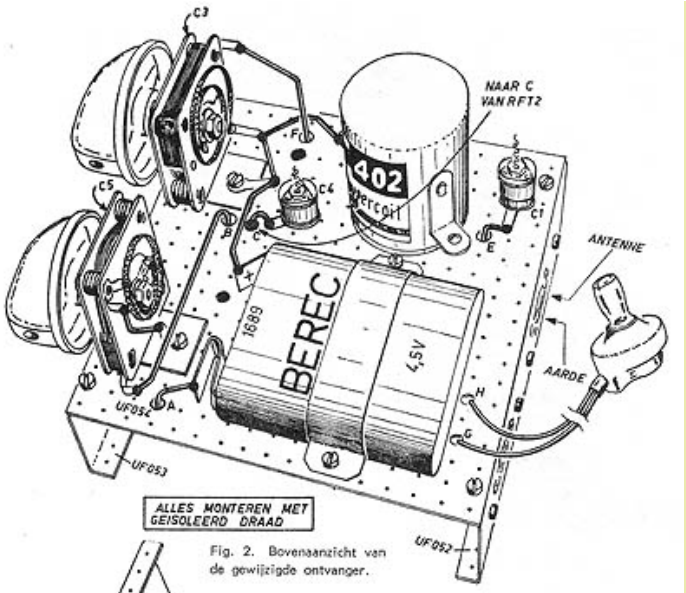


Fig. 2. Bovenaanzicht van de gewijzigde ontvanger.

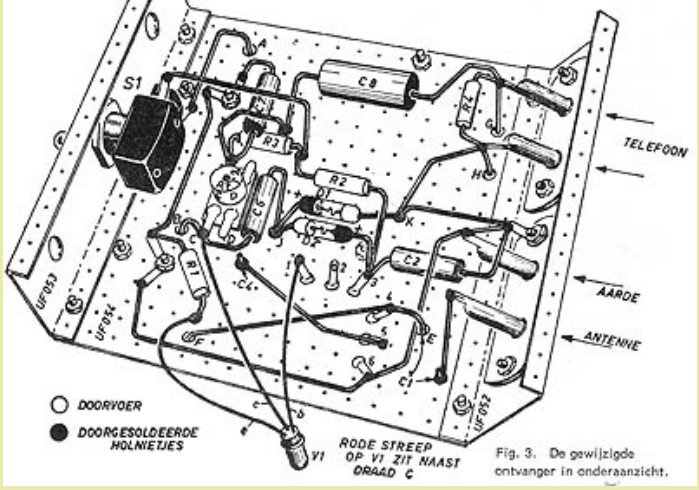


Fig. 3. De gewijzigde ontvanger in onderaanzicht.

The tube radio "ATOM" in the same book was built.
The ATOM receiver was the first radio with a tube. It was a small 7 pin tube for use with batteries. This receiver was not as good as the SUPPLEMENT receiver with 1 transistor, the regeneration control was not so smooth. But it had a good medium wave reception. Unfortunately, this receiver had a very short life. I made a mistake and exchanged the 1.5V battery for the glow wire with the 12V anode battery. A short flash and the tube was dead. There was no money for a new tube...

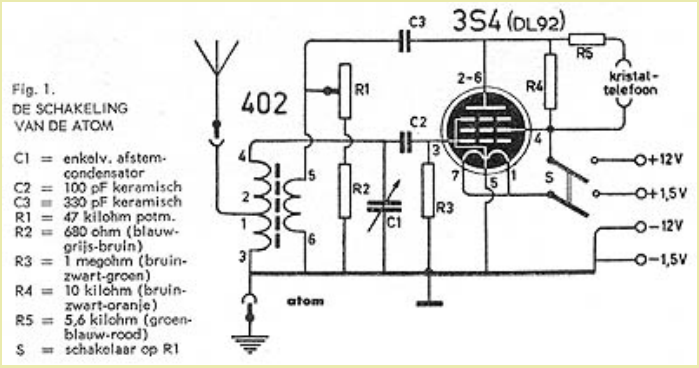
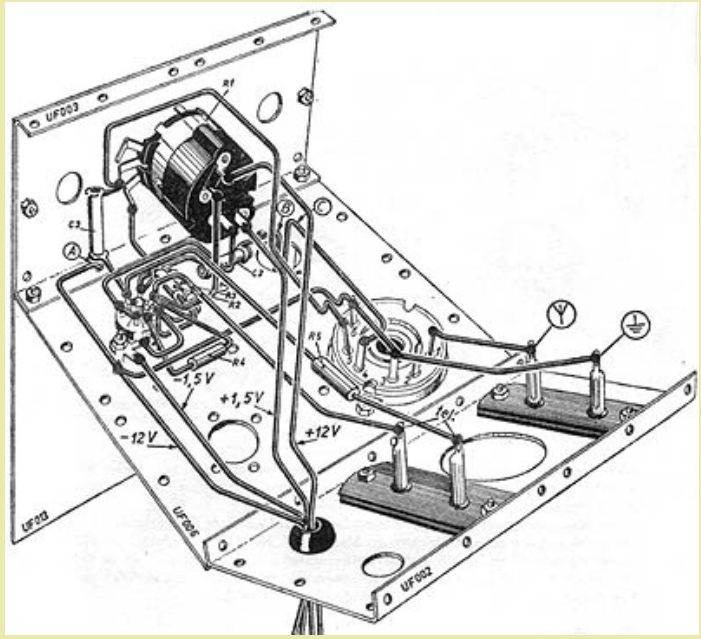


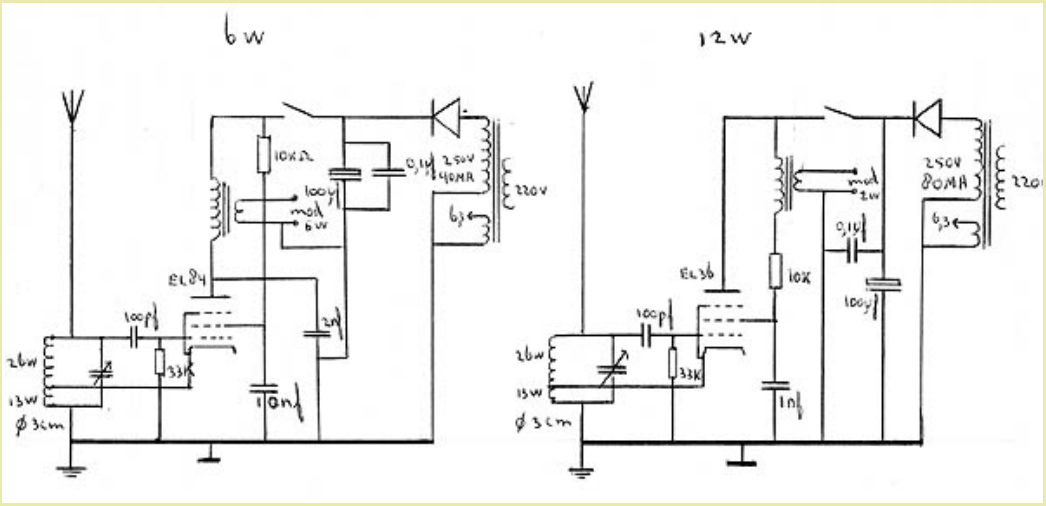
Fig. 1.
DE SCHAKELING VAN DE ATOM

C1	=	enkelv. afstem-condensator
C2	=	100 pF keramisch
C3	=	330 pF keramisch
R1	=	47 kilohm potm.
R2	=	680 ohm (blauw-grijs-bruin)
R3	=	1 megohm (bruin-zwart-groen)
R4	=	10 kilohm (bruin-zwart-oranje)
R5	=	5,6 kilohm (groen-blauw-rood)
S	=	schakelaar op R1

The ATOM receiver was the first radio with tubes. It was a small 7 pin tube for use with batteries. The anode voltage was 13.5V (3 flat batteries in series) and the glow wire voltage came from a fat 1.5V battery. My pocket money was not enough to feed this battery eater...

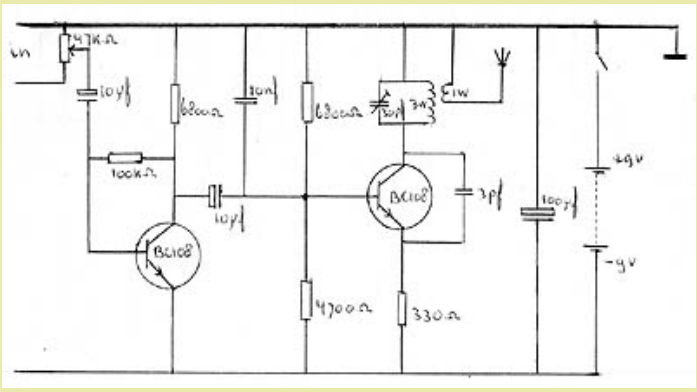


Illegal transmitters.
Of course I made some illegal transmitters. The medium wave transmitters did have a very bad quality, the antenna was a wire of 6 meters long just under the roof. But it was still possible to make contacts upto 10 km distances and the reception was good upto approximately 3 km.

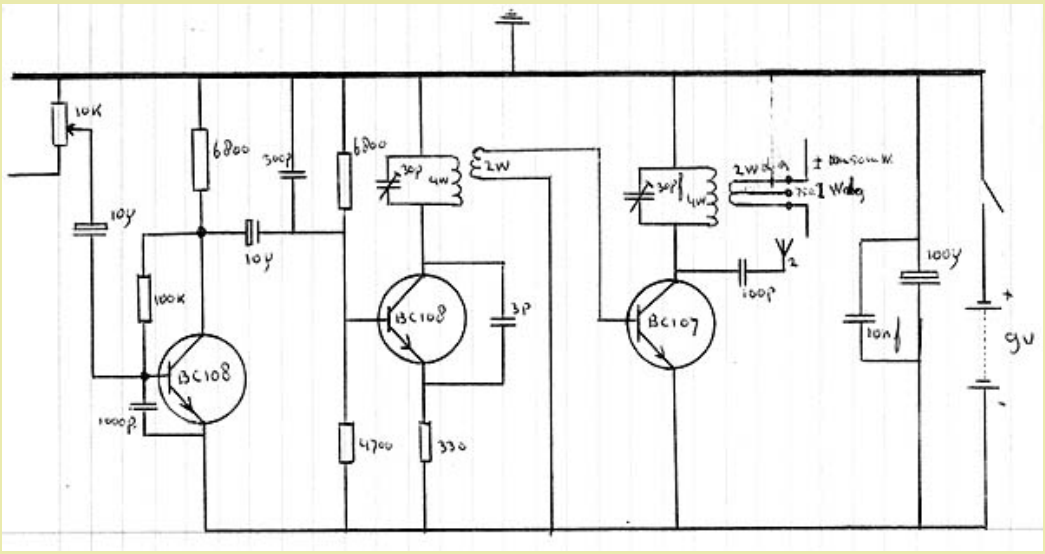


The two medium wave transmitters. Stability was bad. A wire of 6 meters length just under the roof was used as antenna.

Also a few FM transmitters were made. They worked in the then not used frequency range of 100 to 104 MHz. At that time there were no other illegal FM transmitters. They were all on the medium wave.



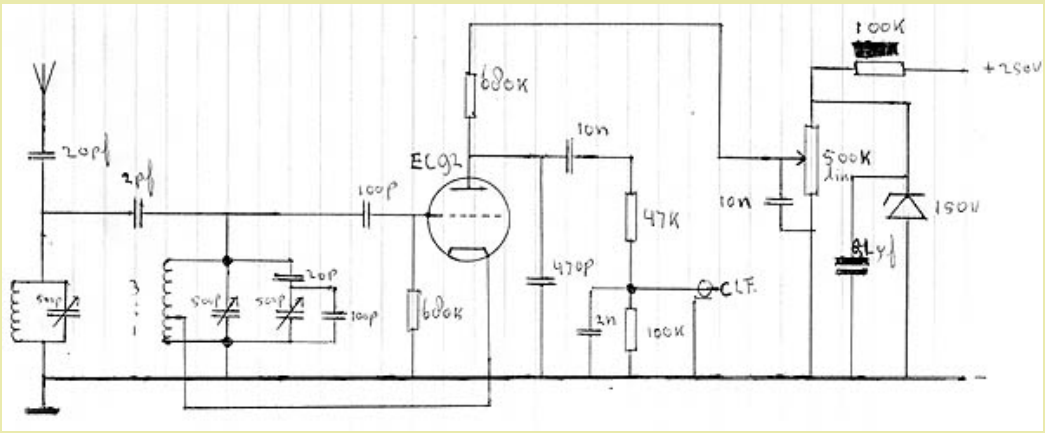
The simple FM transmitter with whip antenna had a range of approximately 1 kilometer.



The FM transmitter with extra final amplifier and dipole antenna had a larger range.

The illegal period lasted only a few months.

The first amateur receiver.
The first amateur receiver was with an EC92 triode and a crystal telephone. It was made for the 80 meter amateur band and many amateurs could be received in SSB. I could not decode Morse yet.



The 80 meter receiver with EC92. The 150 volt zener diode is given the diagram but never installed.

This receiver was built in 1973. I still know that because all amateurs said "Best 73" to each other. I had expected that after the turn of the year it would become "Best 74"...
An extra LC circuit was added between the antenna and the receiver to suppress the strong signals of 40 meter broadcast stations. During the evenings, these will cause whistles in the reception. There are two variable capacitors for the tuning, one for the coarse tuning and one for the fine tuning.
I also modified a medium wave tube radio for 80 meters and later an old radio with red coloured tubes, that could receive the whole band of 1.5 to 4 MHz. A BFO with a transistor was installed in this radio. This BFO on 455 kHz was less stable than the tube radio... Unfortunately there are no photos of these receivers left.

The first amateur transmitter.
The first amateur transmitter was constructed in 1976 and 1977. This 2 meter transceiver could transmit in FM and CW. For the reception of CW signals, the 5.5 MHz IF signal was connected to a Drake SSR1 shortwave receiver. Many FM and CW QSO's were made with this transceiver and also RTTY contacts with an old, heavy and noisy telex.

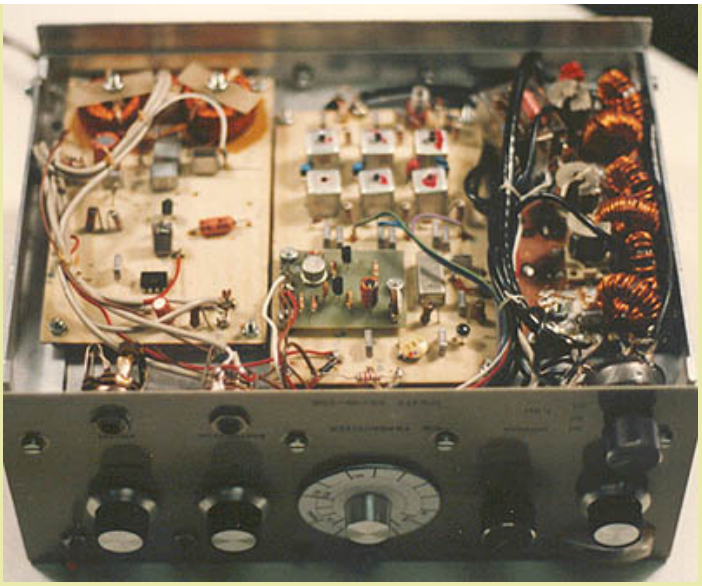


The first amateur transmitter was a home made transceiver for 2 meter. For CW, the 5.5 MHz IF signal was connected to the SSR1 receiver.

RF equipment.
In 1978 a CW transceiver was made. The output power was approximately 5 watts and it could transmit on 80, 40 and 20 meters. The receiver was a direct conversion receiver. Many QSO's were made with this QRP transceiver, also portable. In 1999 this transceiver was completely modified. You can find it somewhere on this website. I also had a TS520 with a very good CW filter.



The homemade CW transceiver.
In 1999 it was completely modified.



It had an excellent CW filter with 88mH coils. Therefore, it was also very sensitive for 50Hz magnetic fields of transformers.

The first computer.
The first computer was bought in approximately 1980. It was a kit, the Acorn Atom and it costed a fortune. Programs were stored on cassettes and a small black and white TV was used as a monitor. The clockspeed was 1 MHz and it had a 6502 8 bits microcontroller inside. There was ROM memory and 8k RAM memory that later was expanded to 16k. I also made an option to put eeproms in a holder. Then it was not necessary to load the programs from the cassette, they were in the 4 k eeprom.



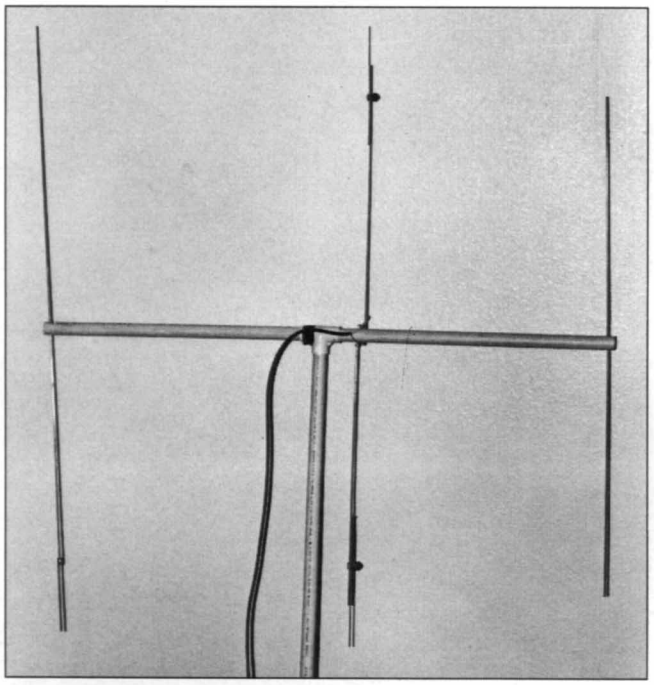
Computer from the time that they did still run barefoot! It was the Acorn Atom. A small black and white TV was used as monitor!

The big advantage of the Acorn Atom was that the documentation was excellent. It was programmable in assembly and a kind of basic. This computer was used for the reception of RTTY (telex) and the transmission of CW. I had many other programs like tone generators, frequency counter, propagation prediction, moon and sun postions, a simple text editor and many others. And it had a real advantage compared to our modern computers: it was ready for use directly after switching it on, only the eeprom type 2716 or 2732 had to be exchanged sometimes!!!

Portable with low QRP power.
In 1977, I became active on the HF bands in Morse code as that works so good with weak signals. To work Portable with low QRP power (only 1 watt) on all kinds of places and weather conditions became a real hobby. This happened with simple homemade CW transceivers with VXO tuning. Especially the simplicity of these small transceivers and the possibility to make so many QSO's with such low power, were very interesting. It was a huge difference compared to working in the shack with the TS520 and 100 watt RF power. How varied is our hobby!!!

Radiosilence from 1982 to 1996.
From 1982 to 1996 there were (almost) no radio activities. There were other hobbies like sailing. I did make a depth sounder with LED bar display and two receivers for weather forecasts and navigational warnings of coast stations.
In 1996 I started again with making a new shortwave receiver. This receiver and other projects after 1996 can be found on this website.

BACK TO INDEX PA2OHH



7 dB for 7 Bucks

By Nathan Loucks, WBØCMT
PO Box 229
Crosby, ND 58730

Need a 2-meter beam antenna, but you're short on cash? You can build this antenna for the cost of a fast-food meal!

When I became active on 2-meter FM, I soon discovered that I needed a beam antenna to hit some of the local repeaters. "Local" in Crosby, North Dakota, means 50 to 60 miles as the crow flies!

I knew there were plenty of VHF antenna projects in *QST* and other ARRL publications. Although many are easy to build, their matching systems are almost incomprehensible for beginners. Just take a close look at a typical matching network and try to figure it out. It's either some kind of a *balun* transformer (that you must wind yourself), a clampy, slidy stub match, or a nightmare of various coils and capacitors! I decided it was time to design, build and test my own beam antenna.

A Little Theory

My three-element beam is really nothing more than a half-wave dipole antenna (the *driven element*) mounted between two other elements known as the *reflector* and the *director*. Typically, the reflector element is about 5% longer than the driven element, and the director is 5% shorter. By spacing elements about 0.15 to 0.25 wavelengths from each other, you end up with a beam antenna with about 7 dB of *gain*. That is, the reflector and director act to shape the energy in a particular direction. By focusing the radio energy in this way, you concentrate the power in the direction you desire (just like a spotlight). That's gain!

To figure out the correct length of my driven element, I used the simple formula for a half-wave antenna above 30 MHz:

$$\text{Length (in feet)} = \frac{475}{\text{Frequency (in MHz)}}$$

At the feed point of a half-wave dipole, the impedance is about 72 ohms—close enough for an acceptable match for typical 50-ohm coaxial cable. Of course, we're talking about a beam antenna, not a simple dipole, so the impedance may be different. Armed with this basic information, I went to work!

Construction

The construction is simple and cheap. I recommend ¾-inch PVC plumber's pipe for the supports. Two 18-inch pieces become the *boom* where the elements are installed. A 36-inch piece is used for the *mast* (see Fig 1). The boom and mast pieces are held together with a PVC **T** joint. Three small holes are drilled in the **T** as well as the boom and mast pieces. Insert the booms and mast into the **T** and rotate them until you align the holes. Now use screws to secure everything in place. You'll notice that my antenna is vertically polarized. This is best for FM work. If

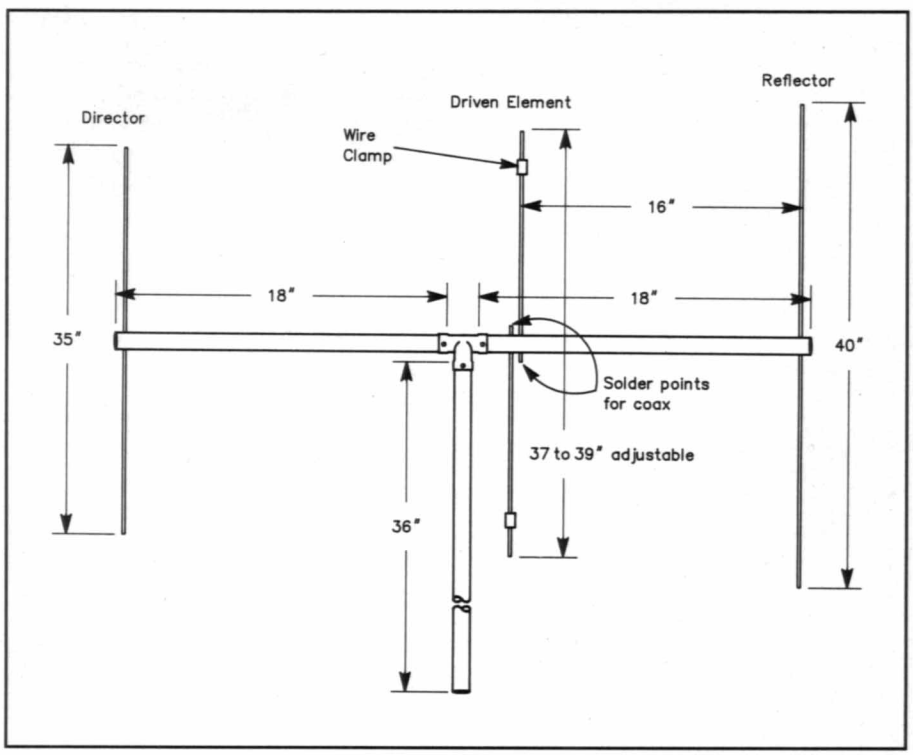


Fig 1—Construction diagram for the 2-meter beam antenna. A few sections of PVC pipe and a handful of welding rods are all you need.

you want to use this antenna for 2-meter SSB and CW, just assemble the boom so the elements are *parallel* to the ground, not perpendicular.

You can make inexpensive elements from steel oxyacetylene welding rods. Hobby stores often carry brass rods that are suitable, too. Cut the director and reflector elements to the lengths shown in Fig 1. (If you can't find a 40-inch rod for the reflector, don't worry. You can solder small pieces at the ends to achieve the total length.) Drill holes in the boom about ¼ or ½-inch from each end. I suggest you use a yardstick to draw a straight pencil line along the boom, marking an **X** for each hole. The idea is to keep the hole positions aligned as you drill them. Choose a hole size that offers a snug fit when you push the rods through.

After drilling, slide the director element through the holes and adjust it until you have an equal length on each side of the boom. Use solder or epoxy cement to hold it in place. Do the same with the reflector element.

Now for the driven element and matching network. But wait! This is too simple. It can't work! Well, my matching device uses a special gimmick. (Those of you from the old school know what I mean.) To construct the driven element, measure and mark the boom about 16 inches from the reflector. Drill two holes about ⅛ to ¼ inch apart. Cut two rods, both 20 inches in length. Push the rods through the holes until ¼ inch protrudes from each side of the boom. You've just made the driven element *and* the matching device!

Solder your coaxial cable directly to the protruding stubs as shown in Fig 2. Use solder and/or epoxy to secure the rods to the boom. Apply electrical tape or use a silicon compound to weatherproof the solder joints.

Tuning

To make tuning the antenna easier over a wide range of frequencies, I clamped 4-inch pieces of welding rod to each driven element with #12 or #14 jam screws (electrical connectors). By loosening the screws and adjusting the rod sections equally, I can quickly tune the antenna for my favorite parts of the band.

Use a *wooden* step ladder to get your antenna at least five feet off the ground. Another approach is to tie a string to the antenna and use the nearest tree branch to hoist it 5 to 10 feet in the air. Once you have your antenna elevated and away from any nearby metal objects (such as aluminum siding and automobiles), place an SWR meter in the line between your transceiver and the antenna. Make sure to use an accurate SWR meter that's rated for operation on the 2-meter band. Now transmit and check the SWR reading. Adjust the clamp sections as necessary to get the lowest reading.

If you want to dedicate the antenna for operation on a relatively narrow set of frequencies (for a particular repeater, for example), don't use the clamp method. Just trim the driven element rods a small amount at a time until you get your lowest SWR reading.

After the antenna is tuned, mount it on the highest point possible (on the chimney or vent pipe, for example). Point the antenna in the direction of your favorite repeater, or use a TV antenna rotator to change direction remotely. If the distance from your radio to the antenna is more than 15 feet, use a low-loss coaxial cable such as RG-213.

That's all there is to it! It's simple, portable, tears down quickly, and best of all, it requires no complicated matching. What more could you ask of an antenna—for just seven bucks?

Nathan Loucks, WBØCMT, is a North Dakota native. He has been a ham for more than 20 of his 38 years. He graduated from the North Dakota State College of Science in Wahpeton. Nathan previously worked for GTE and Motorola in Illinois as a laboratory technician and engineer. He is currently living in Crosby, North Dakota, where he runs a computer sales, telemarketing and consulting business. QST

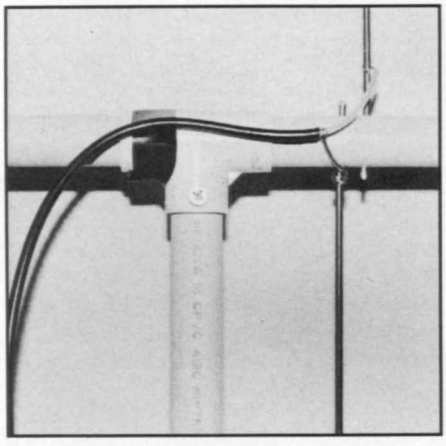


Fig 2—Solder the coaxial cable to the driven element stubs as shown. If the distance from your antenna to your radio is greater than 15 feet, use a low-loss cable such as RG-213.

Radio Tips: Sending Packet Bulletins

If you've tried packet radio, you know what a fascinating mode it is. Through packet radio you can access your local bulletin board (PBBS) and tap into the streams of messages that flow from every corner of the nation and the world. Most of the messages you'll see are *bulletins* intended to be read by many amateurs.

Packet bulletins are terrific tools for gathering or distributing information. If you have something important to say, the packet network can spread your message over a wide area. This is particularly useful if you need advice to solve a problem.

Let's say you have a question and you live in the state of Florida. Here's how you'd address your packet bulletin:

SB ALL @ FLBBS

This means, "Send this bulletin to all packet bulletin boards in Florida." Note that your two-letter state abbreviation is tagged onto the letters "BBS". If you lived in Connecticut, it would be CTBBS.

Depending on your question, this should be sufficient to net several replies. Wait a week or so and see what responses you receive.

If no one responds, you can resend your bulletin with a *regional* distribution:

SB ALL @ SEBBS

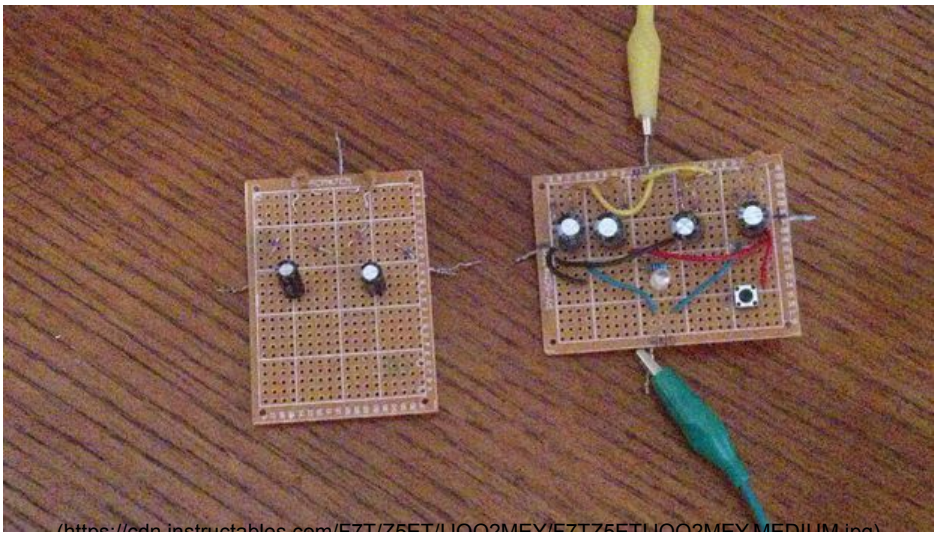
This means, "Send this bulletin to all packet bulletin boards in the southeast (SEBBS)." Once again, wait a couple of weeks for the replies to trickle in.

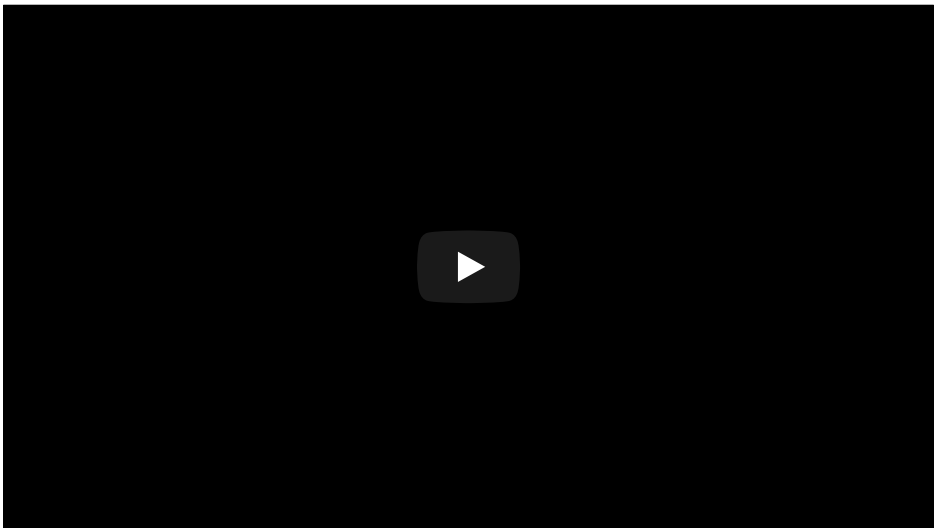
Your last options are to address your bulletin to "USBBS" (every PBBS in the country), or even "WW" (every PBBS in the world). Please use these distribution options with great caution! Ask yourself, "Is my bulletin so important that *everyone* must see it?" Most of the time, the answer will probably be "no." You should reserve the use of USBBS and WW distribution until all else fails.

The packet network is plagued by bulletins unnecessarily addressed to USBBS and WW. These bulletins clog the packet forwarding systems, slowing the movement of more important traffic. By limiting the circulation of your bulletins, you'll be doing a big favor for yourself and your fellow packeteers!—*WB8IMY*

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This video demonstrates a circuit design I found on YouTube called a Nikola Tesla Free Energy Air Circuit. That video showed a hand drawn circuit diagram that looked simple so I decided to build one. Actually, I ended up building a few. This instructable will demonstrate two of the circuits I made. One is just the basic design and the other is two circuits wired in series with a push button to

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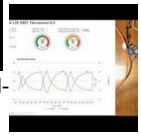
dmainmon (/member/dmainmon/)
Disc Golf Stats (http://www.discgolfstats.com)
(/member/dmainmon/) Follow 65

Bio: Will write code for food. :) If you need help with any of your embedded Arduino applications please send me a message.

More by dmainmon:



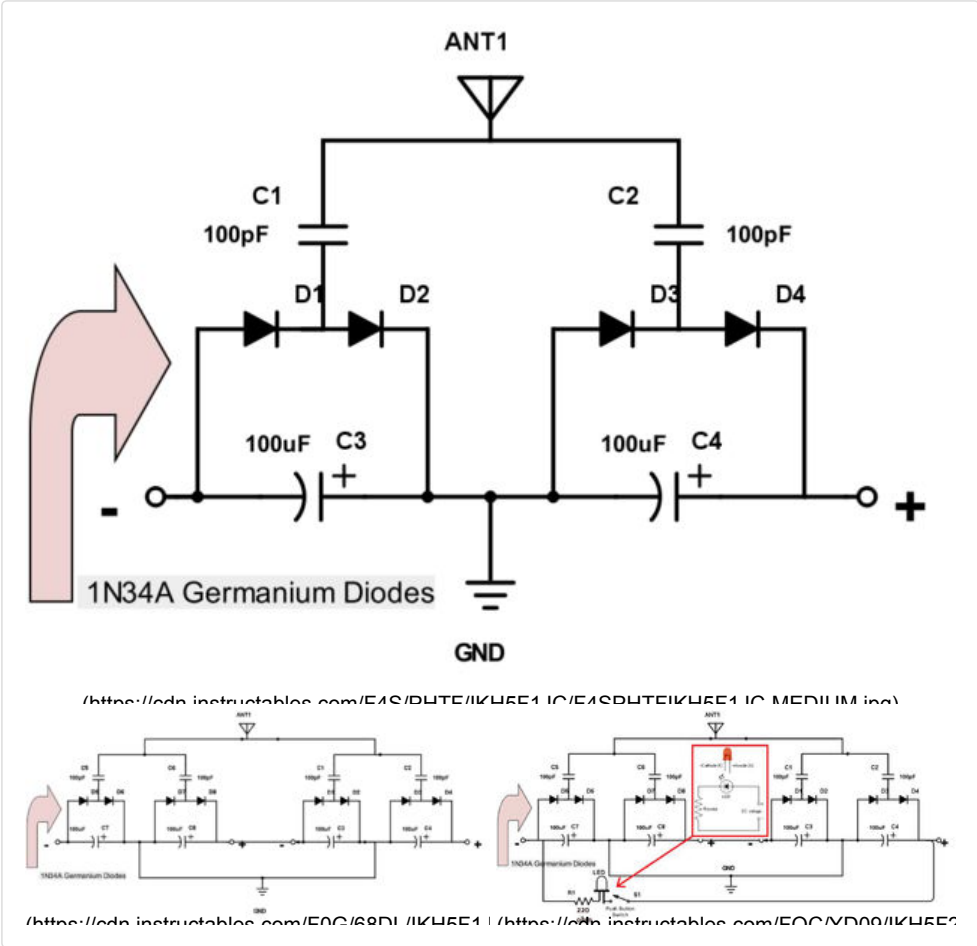
(/id/ArduCAM-Mini-ESP8266-Web-Camera/)


(/id/ESP8266-12E-DHT-Thermostat/)


(/id/ESP8266-OLED-Clock-IoT-Using-AJAX/)

control an led. I connect the circuits to my house ground and an antenna that was already mounted to the top of my house. The antenna was not being used and had been there since I moved in years ago.

Step 1: First, Follow the Schematic to Build the Free Energy Circuit



(https://cdn.instructables.com/F4S/PHTF/IKH5F1JC/F4SPHTFIKH5F1JC.MEDIUM.jpg)

(https://cdn.instructables.com/F0C/68DL/IKH5F1 | (https://cdn.instructables.com/F0C/YD09/IKH5F3

First you need to build the "Tesla Free Energy Circuit". So find a breadboard and follow one of the diagrams above.

The first diagram shows the basic circuit and the second shows the schematic for two wired in series.

You will need at least the following to build the first circuit:

4 diodes (I used 1N34A Germanium Diodes)

2 100pF ceramic capacitors

2 100uF electrolytic capacitors

Step 2: Now Use Antenna and Ground Connect to Test Out the Free Energy Circuit





1. Find a good antenna

You can use whatever you want for an antenna. I use the one mounted to my roof. It's large and works well. Any antenna will work. However, the larger the better usually.

2. Get a good ground connection.

You can use your house ground connection which is usually really good. I've also used a metal stake in the ground (works best if the soil is wet).

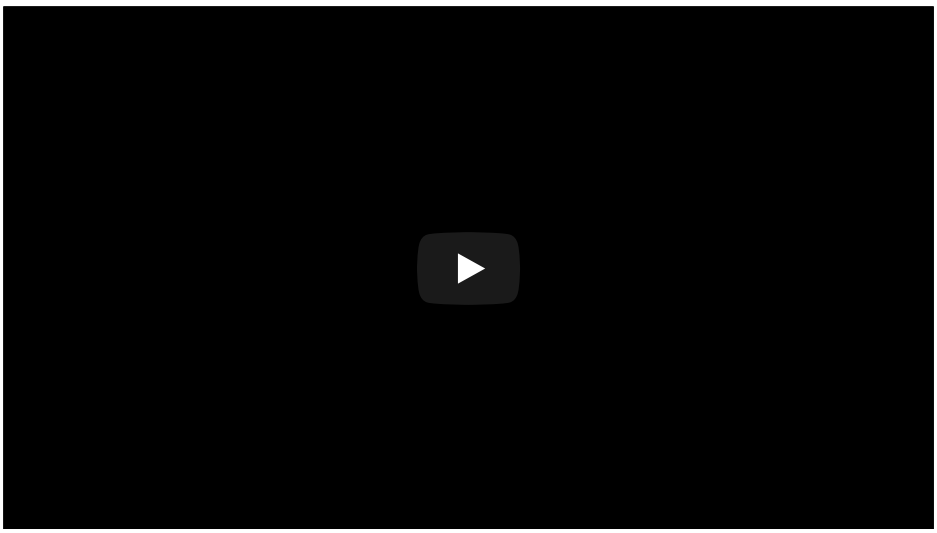
3. Connect a multi-meter and start testing

a. Test the AC voltage of the ground and antenna

b. Test the DC voltage of your circuit (after connecting the ground and antenna to the circuit)

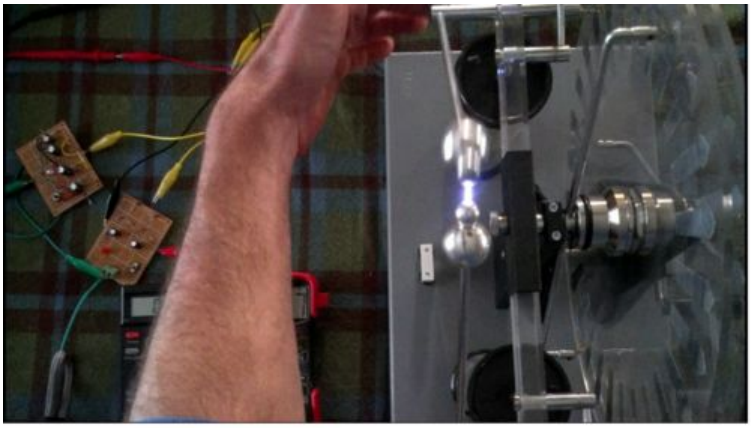
Step 3: After Hours Testing



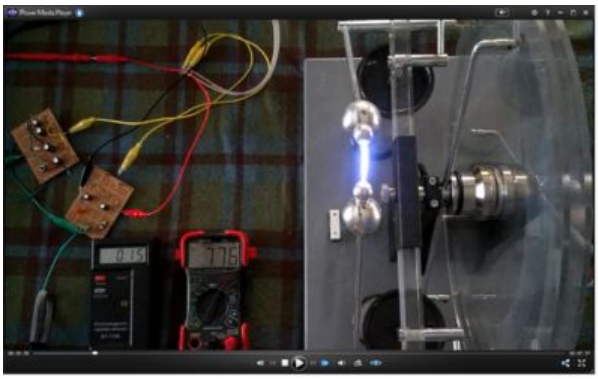


I left both circuits connected to the antenna / ground for a few hours while I processed the video. Later on that evening after dinner I checked the voltage on the first circuit and it was near 20 volts! Keep in mind it's still not that much actual power. It would light an LED for a little while but the voltage would drop off quickly. Just being connected to the multi-meter caused the voltage to slowly start do drop. But over time, if dumped into a battery or larger capacitor bank, you could accumulate enough energy to do something more useful than lighting a LED.

Step 4: Testing With a Wimshurst Machine

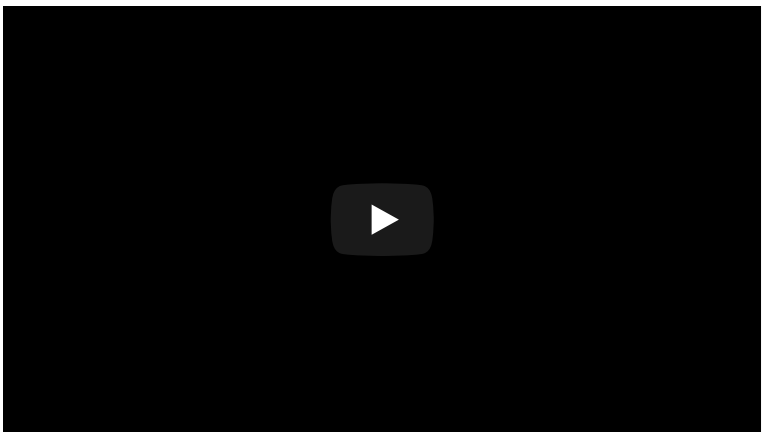


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(https://cdn.instructables.com/FXY/BZ2R/IKRNJ2IT/FXYBZ2RIKRNJ2IT.MEDIUM.jpg)

These tests demonstrate that the circuit receives more than RF (radio) signals. Any electromagnetic radiation can be received. Any electronic device produces an electromagnetic field. These circuits can pick up this energy and convert it to DC power. This video demonstrates the circuit receiving energy "through the air"; otherwise known as induction.



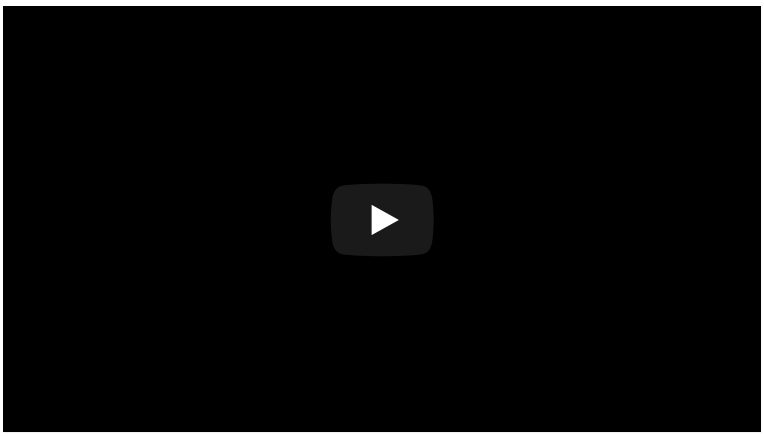
Step 5: Testing With Fluorescent Lighting



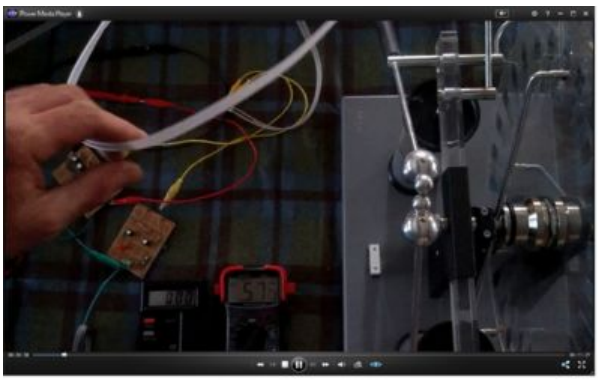




Another observable repeatable test done with fluorescent lights. This test demonstrates two Tesla Air Circuits being tested with fluorescent lights. Proving that these circuits receive more than just radio (RF) signals. These circuits will harness energy from anything that produces a strong enough electromagnetic field. Anyone with the desire to build the circuit can demonstrate this proof of concept by repeating the tests.



Step 6: The Story Behind the Testing



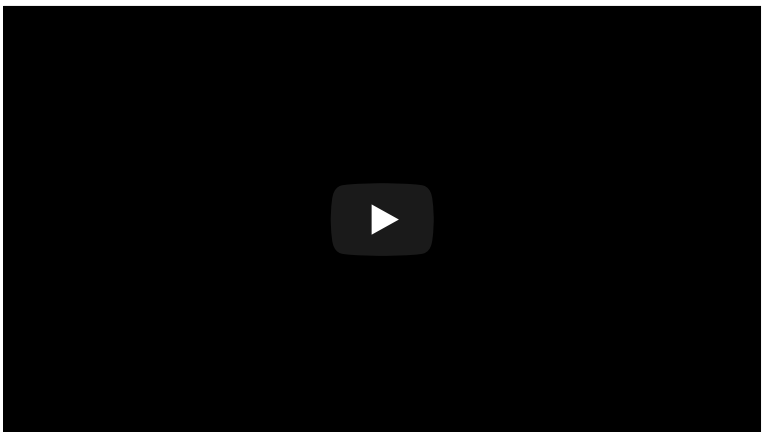
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More Tesla Air Circuit demonstrations and tests. Plus, the story behind the project and testing. I noticed that the circuits performed better at night. Find out why in the video.



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Please be positive and constructive.

I Made it! Add Images Post Comment

discostu956 (/member/discostu956/) 2016-01-23 Reply

any idea what sort of power you can get out of this?

I was actually wondering recently if you can get usable electricity from an antenna, so this answers it for me. I'm guessing the stronger the signal and higher the transmission power the more electricity. Cool project, thanks for sharing

dmainmon (/member/dmainmon/) ▸ discostu956 (/member/discostu956/) Reply

2016-01-23

After a few hours the single circuit reached nearly 20 volts. The double circuit reached over 8 volts. I had been pushing the button so it had only charged a couple hours; less than the single circuit.

I posted a "Step 3" that shows another video and picture to demonstrate.

rickharris (/member/rickharris/) ▸ dmainmon (/member/dmainmon/) Reply

2016-01-24

We are awash in radio wave many of which come from high power sources such as commercial radio stations. Tapping into this sea of energy is of course possible and by no means mysterious. If you include a tuned circuit, a coil and capacitor you will get even higher levels of power "sucked from the air"

On a small scale this is no more than what a crystal radio does, on a larger scale, large enough to be useful your going to upset a lot of people by creating black spots in their transmission pattern, it won't take them long to find the source of the problem.

Free energy? 1. this isn't really free as the transmitted signal has to be paid for 2. Free energy doesn't, as such, exist. energy can neither be created or destroyed, only changed from one type to another. If anyone wants to extract "free" energy they will be bett off looking at solar, wind or water power.

ImBarticus (/member/ImBarticus/) ▸ rickharris (/member/rickharris/) Reply

2017-05-24

Tesla was doing this before radio and the electric grid

rickharris (/member/rickharris/) ▸ ImBarticus (/member/ImBarticus/) Reply

2017-05-25

https://en.wikipedia.org/wiki/Wireless_power_trans...
(https://en.wikipedia.org/wiki/Wireless_power_transfer)

That wasn't my point.

Tesla Free Energy Air Circuit Design and Testing

by dmainmon (/member/dmainmon/) in electronics (/technology/electronics/)

Download (/id/Tesla-Free-Energy-Air-Circuit-Design-and-Testing/) 6 Steps Collection I Made it! Favorite Share

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This type of energy leech is "cashing in " on the wealth of high power radio transmissions that surround us.

It isn't extracting energy from the ether. And neither did Tesla.

MORE INFO



ThomasK19 (/member/ThomasK19/) ▸ rickharris (/member/rickharris/) Reply

2016-01-24

I was about writing just the same xD Really spooky how people turn science into abracadabra. Recently I saw those chemtrailers. I did not know whether to laugh or to run and cry.



nnadine1973 (/member/nnadine1973/) ▸ ThomasK19 (/member/ThomasK19/)

2016-08-01 Reply

Unfortunately you should cry. The level of idiocy is higher every day, and growing.

People that have no basic knowledge claim "over unity" ,"perpetuum movement" or "free energy". Less and less people try to read a book. We are going down, and fast.



discostu956 (/member/discostu956/) ▸ nnadine1973 (/member/nnadine1973/)

2016-08-01 Reply

nnadine: there is free energy and there is free energy, both with different meanings. My assumption with this instructable was that it was referring to energy that didn't cost anything, hence "free", rather than an over unity type impossibility. From the comments being written it seems that a lot of people haven't considered this other, more common, meaning of the word "free", and frankly have voiced that fairly rudely.



rickharris (/member/rickharris/) ▸ discostu956 (/member/discostu956/) Reply

2016-08-01

This isn't free in any sense other then your not paying for it. The transmitters, and the users of that transmitted energy would be very cross with you for blanking out their reception if you were to try to draw any amount of power from the air.

Whilst on this type of "free" energy you can get 50 volts from your phone line. It's free in so far as you won't pay any more for tapping it;. - The phone company take a dim view though.



ThomasK19 (/member/ThomasK19/) ▸ discostu956 (/member/discostu956/) Reply

2016-08-01

Actually I had this discussion in a similar i'ble: there is no free energy (in the sense of available, but you must not pay). What you harvest is electromagnetic energy and there is plenty out there. Unfortunately the part not originating from humans compared to the part made by humans is nada/almost all. So you will just harvest energy made by humans. And it is NOT the case that this will just "float around" and needs to be gathered. Most of it is from radio stations and what you take away must be put in additionally at the radio station. So, if you harvest that energy on a larger scale it's simply stealing. Nobody will care if you operate a LED with that energy. But doing this serious is: stealing. So don't start talking about free energy. There is none.

discostu956 (/member/discostu956/) ▸ ThomasK19 (/member/ThomasK19/)



Yeah, I should have said doesn't cost anything to the guy at the end with the circuit having a play around. It's what I meant when I wrote the above post, and like I said there it's what I figured was meant the whole time with the term "free energy" in this and other instructables.

2016-08-01 Reply

My real gripe really is that people don't need to say it rudely, there is a be nice policy on here (not referring to you here). Nothing wrong with saying it though

ThomasK19 (/member/ThomasK19/) ▸ nnadine1973 (/member/nnadine1973/)

2016-08-01 Reply

You got inspired by the comment from bodo below, I guess :o)

There are quite some of those i'bles here. Unfortunately it's true - less people care for truth. "I read that on the internet" seems to be enough.

bodo (/member/bodo/) ▸ discostu956 (/member/discostu956/) 2016-04-07 Reply

it depends on he sumation of thecirquits asmach as you can connect in paralle you gat asmauch power

McantonyP (/member/McantonyP/) 2017-01-16 Reply

Hello

which antenna did you use?

Thank you

emp0001 (/member/emp0001/) 2016-10-02 Reply

Hello,

which voltage rectifier you used ?

Thank you.

nnadine1973 (/member/nnadine1973/) 2016-08-01 Reply

Nothing 'free' here. You made a receiver. I used this 30 years ago to power up a small bulb, nothing more. The energy is coming from the radio stations around so, theoretically, with a very long antenna and decent earth plug, may squeeze out about 1or2 watt .

tony17837 (/member/tony17837/) 2016-01-24 Reply

c
Cool Demo. The energy is however not really Free. It is being radiated by from RF sources in you area. For example you local FM rock station. what you have built is a radio receiver. If you added a oscillator to the circuit and tuned it, you might be able to hear Air Supply or Tay Tay if you're lucky.

dmainmon (/member/dmainmon/) ▸ tony17837 (/member/tony17837/) Reply

2016-04-05

While the circuit does convert RF signals to DC power, radio frequencies are NOT the only source this circuit can receive. In Step 5 of this instructable the circuit is tested with fluorescent lights(https://www.instructables.com/id/Tesla-Free-Energy-Air-Circuit-Design-and-Testing/step5/Testing-with-Fluorescent-Lighting/) The circuit will pick up and convert the frequency emitted by the fluorescent lighting ballast.

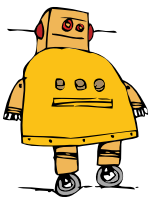
russ_hensel (/member/russ_hensel/) 2016-01-24 Reply

20 volts or even 1000 volts is not energy, it is potential energy. To get energy out of it you must have charge flow, or current. Since current is charge/time, current * voltage = power.
Allow some current to flow, measure it, do the math, and let us know how much power you are able to harvest.

This is free energy in the sense that you do not have to pay for it (except the capital cost of the device). It does not violate thermodynamics, or extract the so called "vacuum energy"

Nice Idea and execution, let us know some more results please.

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IMPROVED 30 METER RECEIVER FOR LOW POWER QRSS BEACONS AND PSK31

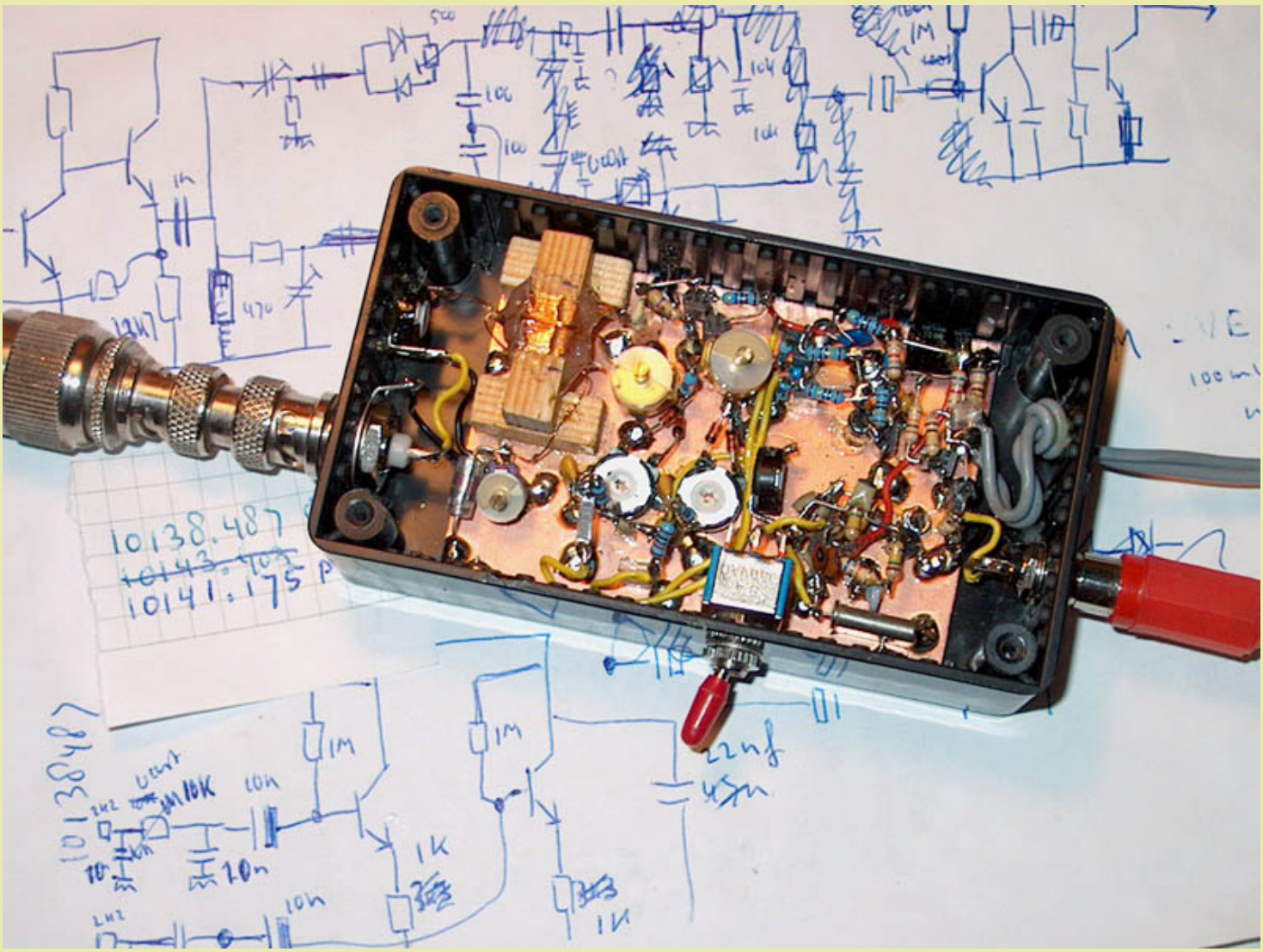
(2009)

KLIK HIER VOOR DE NEDERLANDSE VERSIE

Reception of very low QRSS beacon transmitters

It seems unbelievable. During my holidays in Spain, it was possible to receive a 10 milliwatt beacon transmitter located in The Netherlands at a distance of 1650 km!

There is a group enthusiastic radio amateurs that is doing experiments with very low powers. That is possible by using a very slow CW speed. QRS mean reduce your CW speed. With that extra S of QRSS they want to indicate that it is really a very low CW speed. A point lasts 3 or 10 seconds. Most of the activities take place in a band of only 100 Hz: 10140.0 to 10140.1 kHz in the 30 meters amateur band. The signals are so weak, that you cannot hear them. But you can see them on the monitor of the PC. The audio output of the receiver is connected to the sound card of the PC. With a special software program, you can make bandwidths of 0.3 Hz or even less and display the signals on the monitor.



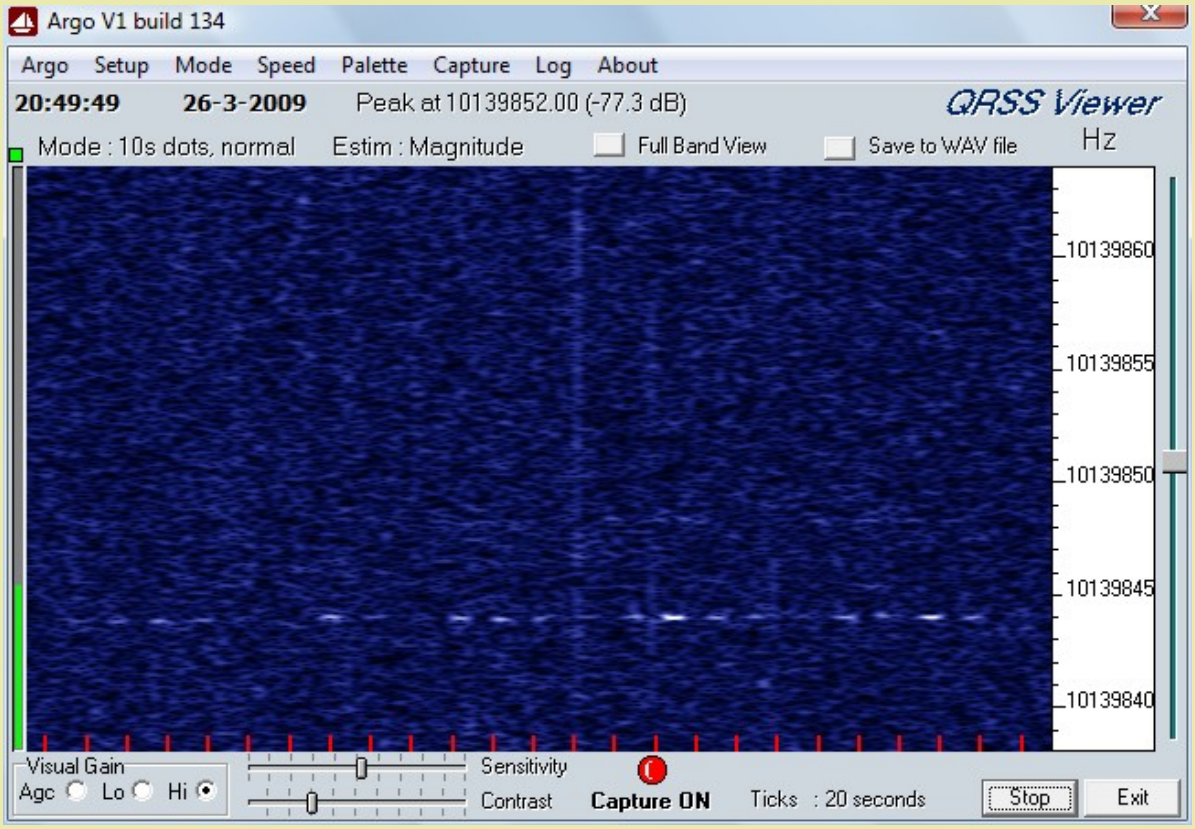
From double side band to single side band reception! In the improved receiver, the unwanted side band is suppressed with the phase method.

From double side band to single side band reception and from 10 milliwatt to 1 milliwatt

The experiment was successful with 10 milliwatt in the 30 meter amateurband. The new challenge was to try it with 1 milliwatt or a factor 10x or 10 dB lower. That is 1000x lower than the 1 watt of my small QRP transceiver!

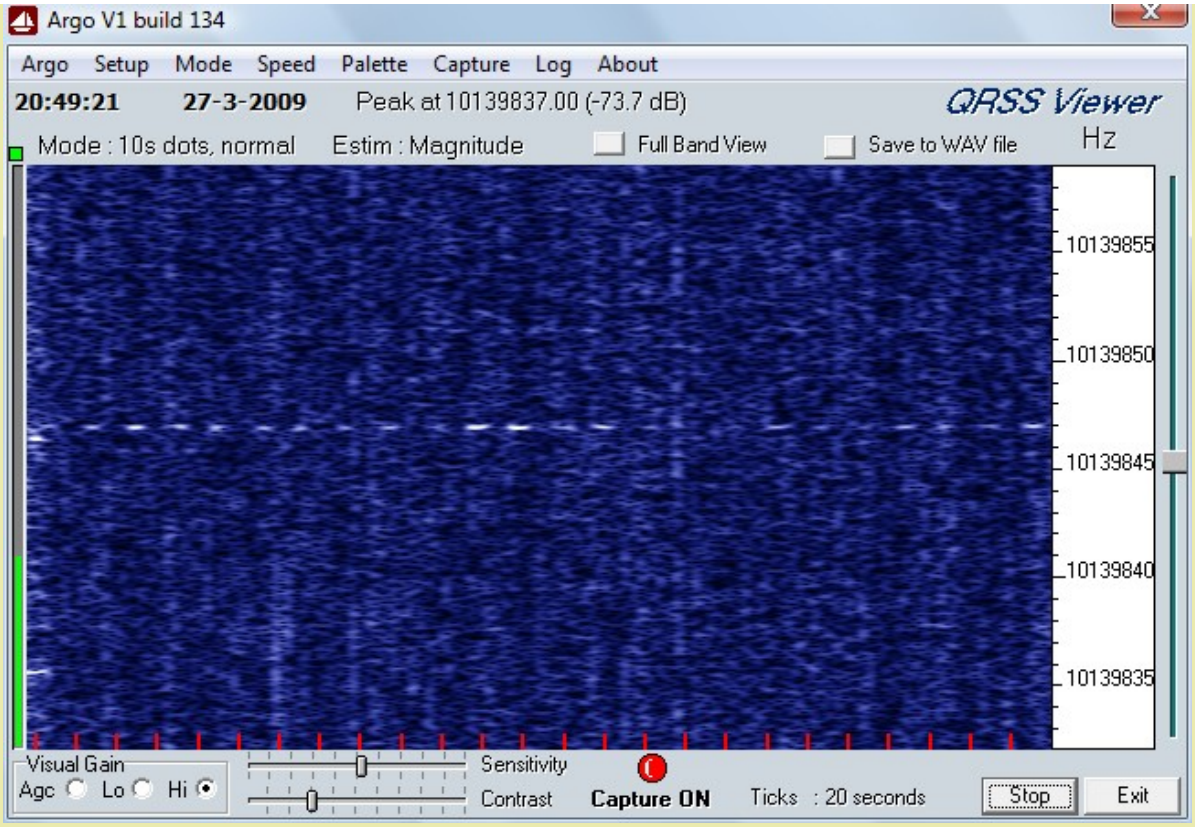
A gain of 3 dB can be obtained when the direct conversion receiver is modified from a double side band receiver to a single side band receiver, as the noise of the unused side band is suppressed then. And 5 dB gain by setting the dotlength of the software program ARGO to 10 seconds instead of 3 seconds. In total, we would have 8 dB gain, or almost the 10 dB power reduction!
There was some space left in the plastic housing of the simple direct conversion receiver. Just enough to modify the simple receiver with the phase method to a single side band receiver.

The beacon transmitter was also modified. The transmit times were extended and the power was reduced. During the low shift, the power is 1 milliwatt, during the high shift even lower, 0.1 milliwatt. Should it be possible to receive that 1 milliwatt and 0.1 milliwatt during holidays in Spain? Here below the result.



The beacon signal with a shift of 4.2 Hz, 10 s low shift with a power of 1 mW.
So the 1 mW beacon could be received at a distance of 1650 km!
Even a very weak trace is just visible of the 13 s high shift of 0.1 mW.

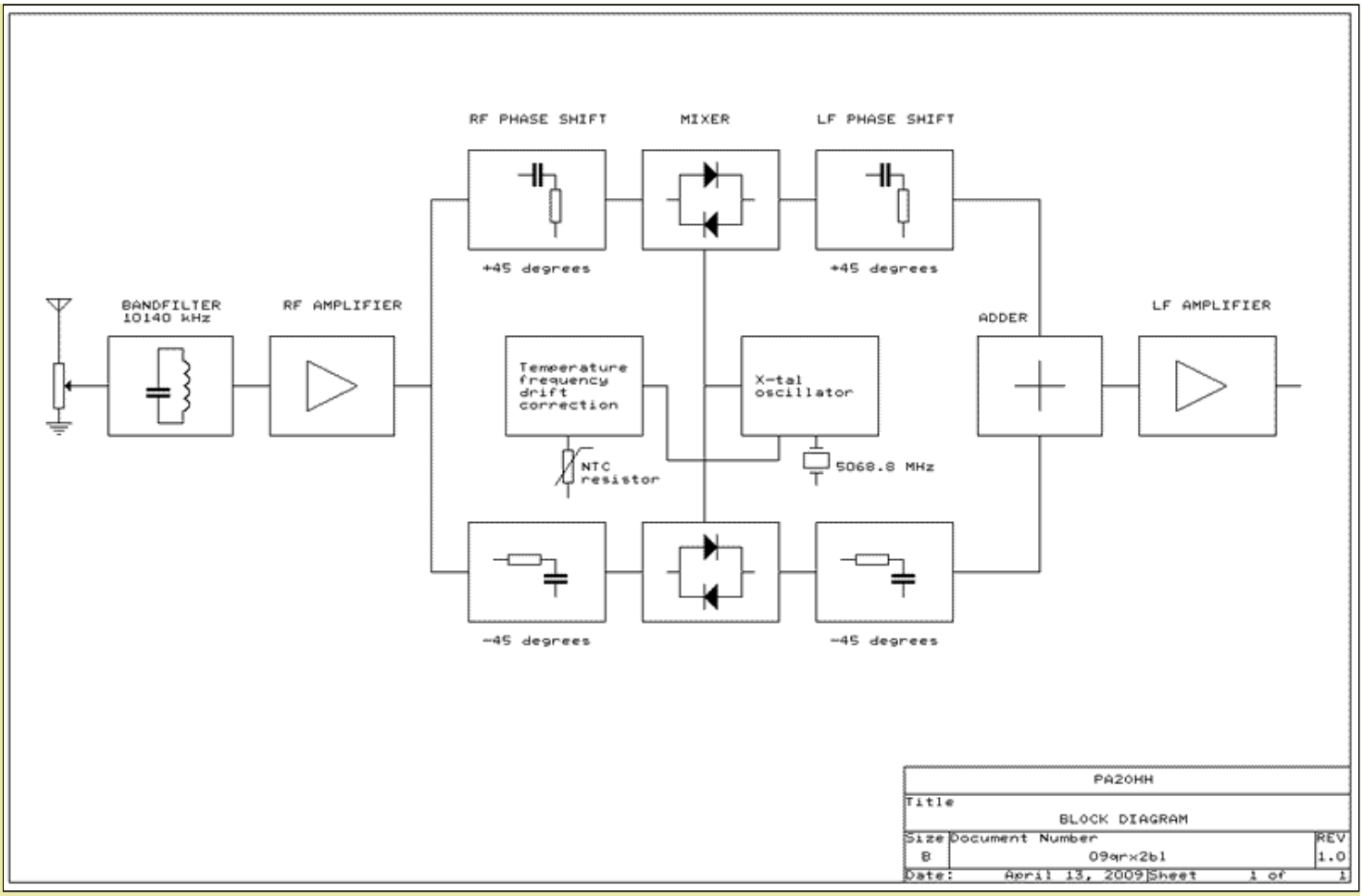
Of course, everything has to go well. The conditions have to be excellent, the interference in a dip, you need to have the luck that you are listening just on the right moment, the frequency drift of the transmitter and receiver have to be minimal. You can receive the weak signal only at those excellent moments. It is important that your receiver is tuned to the frequency of the transmitter with an accuracy of plus or minus 30 Hz, so that you are looking at the right frequency when the conditions are good.



Here a registration during 8 minutes. Unfortunately there was much QRN that evening, otherwise, the 4.2 Hz higher 0.1 mW signal perhaps had been clearly visible!

Modified receiver with side band suppression

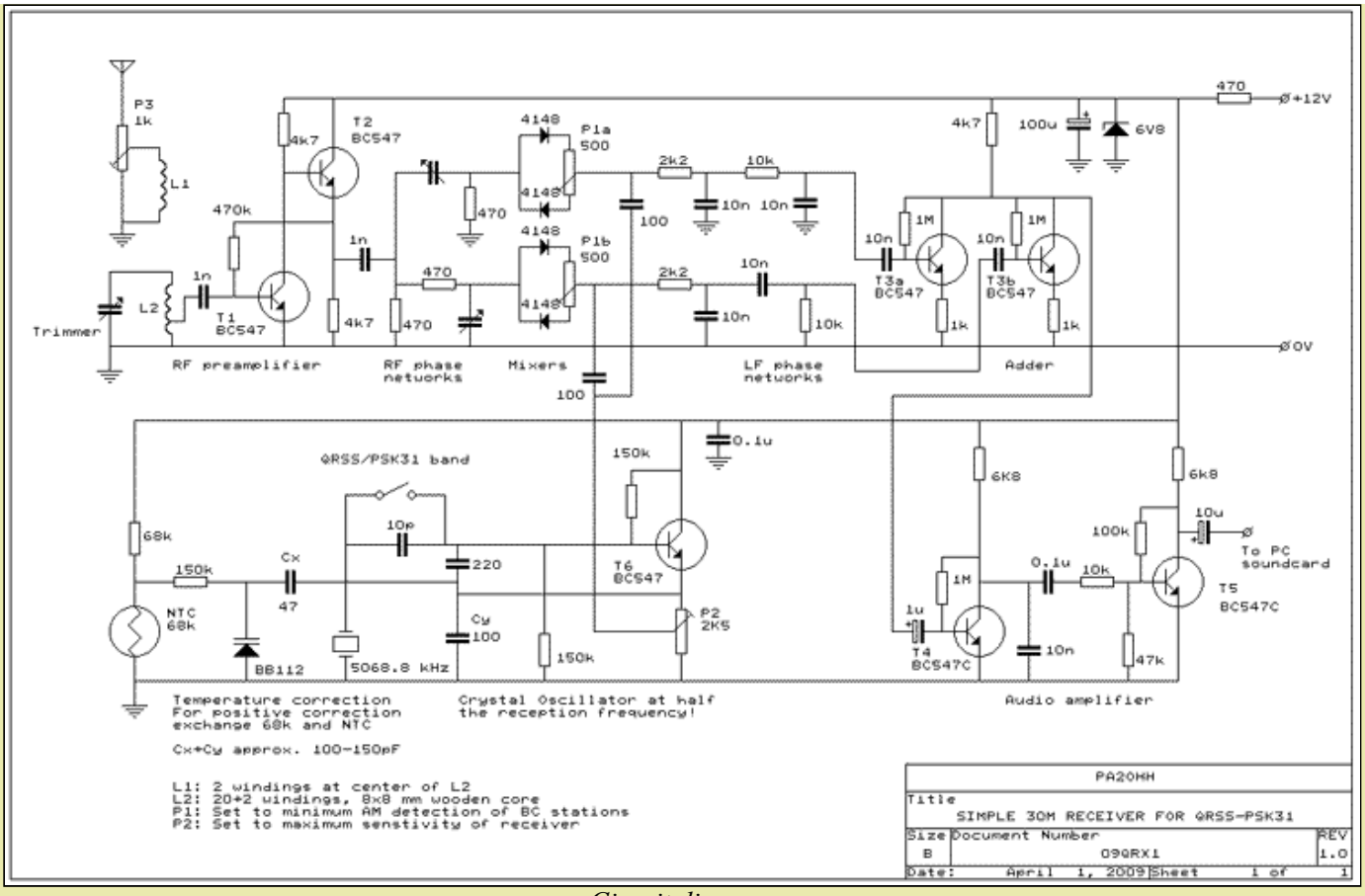
It was quite simple to modify the simple direct conversion receiver with the phase method to a single side band receiver. Two mixers were required instead of one and simple phase networks in the RF part and LF part. As the frequency band of 10140.0 MHz to 10140.1 MHz is only 100 Hz wide, we can use two very simple LF phase networks consisting of one capacitor and one resistor. That is an advantage, because there is not so much space in the plastic housing of the receiver. And the receiver has to be supplied with batteries, these networks do not require any current. A wide band 90 degrees phase networks with op-amps in the audio part was not possible.



Block diagram. The phase networks do suppress 1 side band.
The Poljakov mixers do need a local oscillator signal of half the reception frequency.

Explanation of the schematic diagram

A part of this explanation is a copy of the explanation of the first version of the receiver.
We will start with the RF amplifier and RF phase networks. T1 is an ordinary LF transistor. The tuned circuit is adjusted by ear for maximum sensitivity. L2 is 20 windings on a wooden core of 8x8 mm with a tap at 2 windings to the base of T1. The antenna winding L1 of 2 windings is wound over the center of L2. The (adjustable) potentiometer P3 of 1k is the RF control. It is used to avoid overloading of the receiver in the evening by strong broadcast stations. You can use an adjustable potentiometer as it is not adjusted so often, only once or twice per day.
T1 is followed by an extra transistor T2 that transforms the high output impedance of T1 to a lower impedance. That is necessary to feed the phase network.
There are two 45 degrees phase networks between the RF stage and the mixers. They are adjusted by the trimmers. For that purpose, you do need a signal at the unwanted side band. Adjust the trimmers by ear to maximum suppression of this signal. You have to repeat it a few times, as the settings of each network do influence each other.



Circuit diagram

[big diagram]

Mixer and LF phase networks

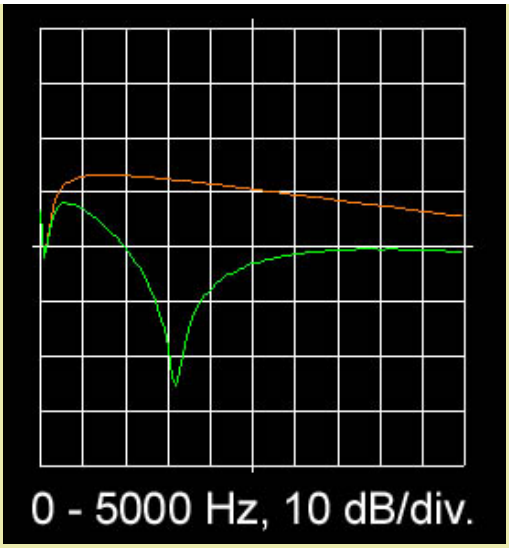
The mixer is a so called RA3AAE or Poljakov mixer. It works with a local oscillator signal of half the reception frequency. And that is the frequency of a cheap, easily obtainable crystal of 5068.8 kHz. The oscillator level is quite important and can be adjusted by ear with P2.
With a good adjustment by ear of P1a and P1b, the sensitivity for strong AM signals can be reduced considerably.
After the mixer and the RF decoupling networks consisting of resistors of 2200 ohm and capacitors of 10 nF, you will find the LF phase networks. Each network is made of a capacitor of 10 nF and a resistor of 10 k ohm. The networks are designed for 1550 Hz, that is the center frequency of the 10140.0 - 10140.1 MHz band in my receiver. You have to modify them for other frequencies.

VXO

The crystal oscillator works approximately on 5068.8 kHz, just beside half the reception frequency. The exact value is not important, it is set during the calibration and corrected in the ARGO software program. By means of a switch and an extra serial capacitor, the frequency can be increased so that you also can receiver PSK31 stations working at higher frequencies..

Temperature stabilization

With a NTC resistor and a varicap, a temperature correction was designed and the drift reduced to less than 5 Hz between 10 C and 30 C. For an upwards frequency correction, the NTC has to be connected as in the diagram. For a downwards correction, exchange the NTC and 68k resistor. Of course you can also take a NTC resistor with another value. Exchange the 68k resistor then for a resistor with the same value as the NTC. Increasing Cx and reducing Cy increases the correction, reducing Cx and increasing Cy reduces the correction. Finding the correct value is a question of trying out while cooling down and warming up the receiver with various values of Cx and Cy.



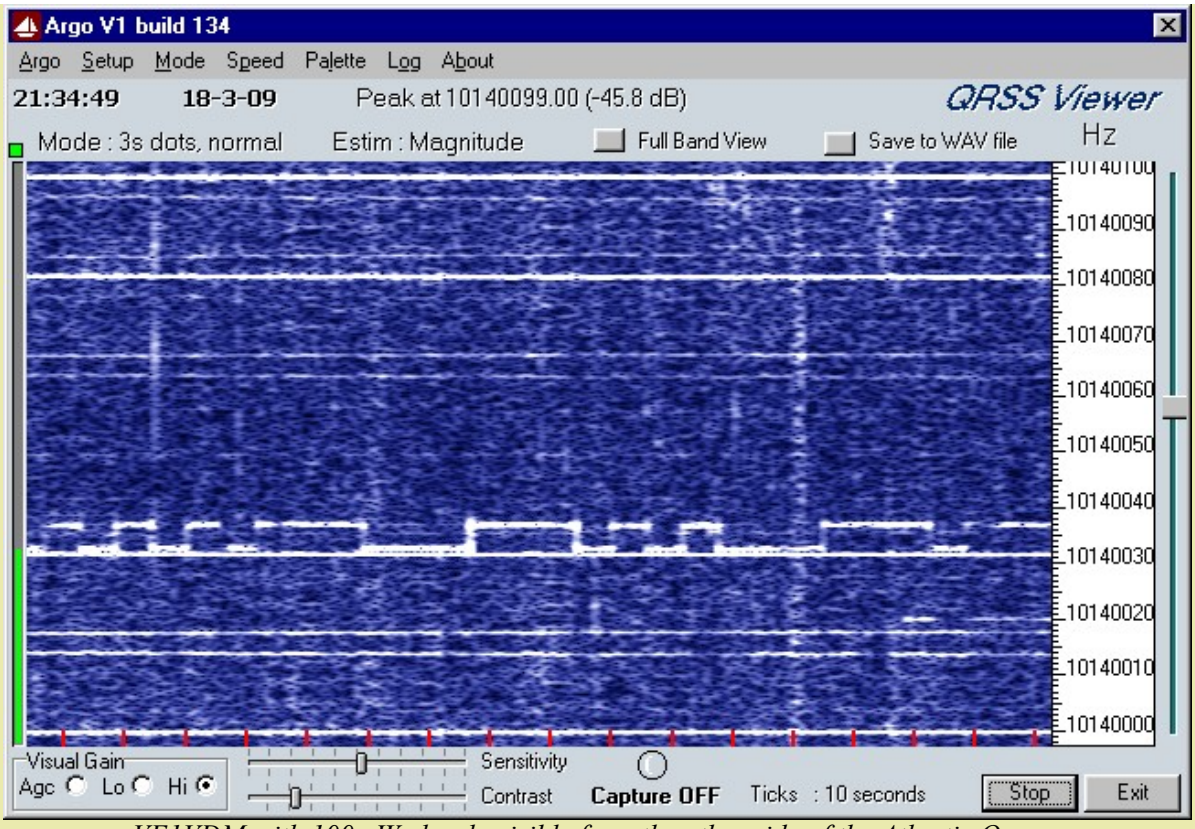
Frequency characteristic (orange line) and side band suppression (difference between orange and green line).

Side band suppression
The orange line is the frequency characteristic of the receiver. It is quite wide, at 5 kHz, the receiver is approximately 10 dB less sensitive, at 10 kHz approximately 20 dB. The green line is the unwanted side band. The difference between the orange line and the green line is the side band suppression. In my receiver, the band 10140.0 to 10140.1 MHz is mixed to an audio band of 1500 - 1600 Hz. As you can see, the side band suppression in this band is at least 30 dB, despite the simple phase networks! And between 1300 - 1800 Hz still 20 dB. Enough to suppress the noise and therefore to increase the sensitivity with 3 dB But not enough to suppress strong signals. Happily this hardly occurs.

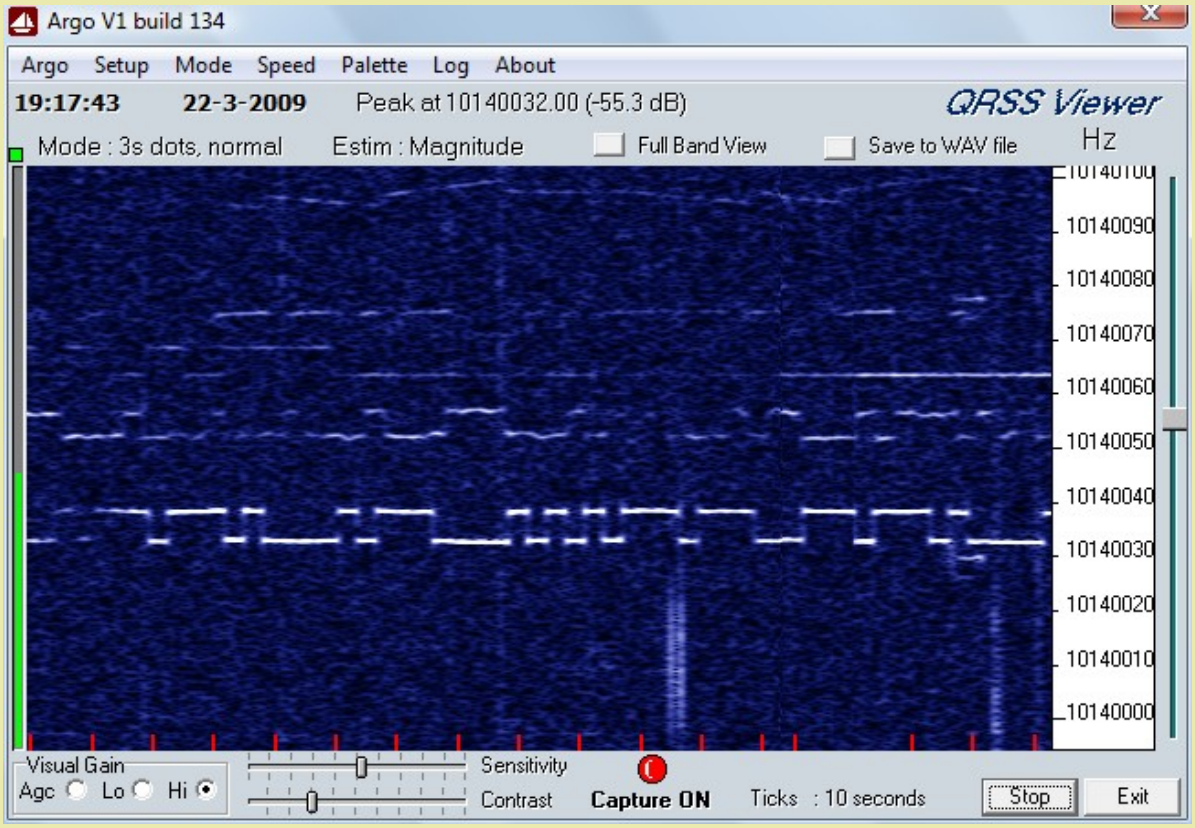
Alignment of the receiver
The tuned antenna circuit at the input is aligned by ear at maximum sensitivity.
The temperature correction is adjusted by warming up and cooling down the receiver with various values of Cx and Cy.
The oscillator level is adjusted by ear at maximum sensitivity. Adjust it a little higher, so that the sensitivity decreases a little. At that point, the suppression of strong AM broadcast signals is better.
The potentiometers P1a and P1b are adjusted with a strong AM signal in the 10 MHz broadcastband for a maximum suppression of AM detection. If possible, use a (simple) AM modulated signal generator.
The two 45 degrees phase networks are adjusted by ear with the trimmers. For that purpose, you do need a signal at the unwanted side band. Adjust the trimmers by ear to maximum suppression of this signal. You have to repeat it a few times, as the settings of each network do influence each other. If you want, you can optimize the side band suppression by changing the values of the resistors in the LF phase networks a little. Then repeat the alignment of the trimmers of the RF phase networks.

Software
You can find much information and software about QRSS on the internet. I do use ARGO of Alberto, I2PHD and Vittorio, IK2CZL. I also do use Spectran, because that has the possibility to listen to the received signals. My laptop does not have the possibility anymore to redirect the input signals directly to the built-in speakers. When you do use the microphone input, switch off the 20 dB boost. If the audio signal is too strong, then you can increse the 10k resistor in the base of T5 to 47k.
For uploading the screenshots, I use Argo Upload by Rik Strobbe (ON7YD). It makes it possible to see via the internet what the receiver at home does receive. So now and then you can look at the live ARGO pictures of my receiver via internet: grabber.htm, the pictures are refreshed approximately every minute.

Some more results
Although the results are not bad at all, it is not a very good receiver. Quite often, the RF attenuator has to be used to eliminate the AM detection of strong broadcast stations. And the audio band is too wide. For really good results, a better receiver has to be made. But that will be much more complicated!
The sensitivity is good, with ARGO and a dotlength of 3 seconds, a signal of -140 dBm could easily be detected. Also the noise increases when the antenna is connected, even with some RF attenuation. Here below some more results.



VE1VDM with 100mW clearly visible from the other side of the Atlantic Ocean.
With much unaudible, but visible interference from a television receiver!



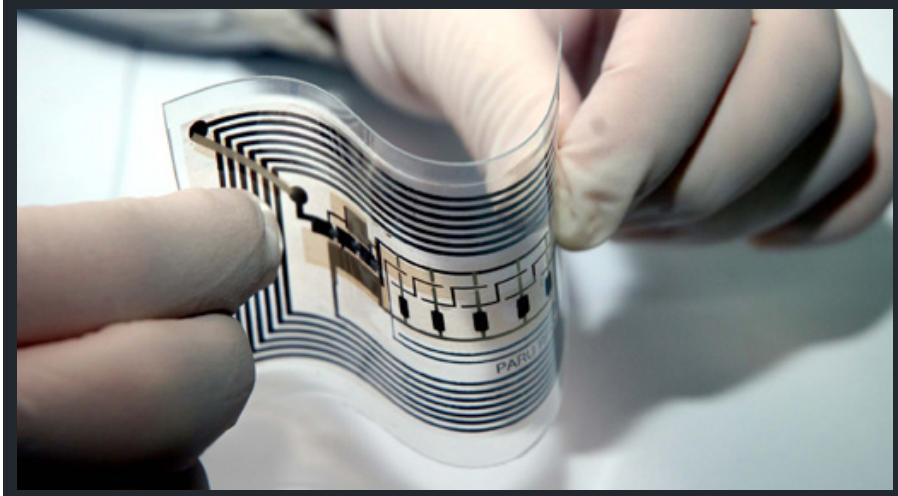
PA3GFE, received during holidays in Spain (IM98WU).

BACK TO THE INDEX PA2OHH

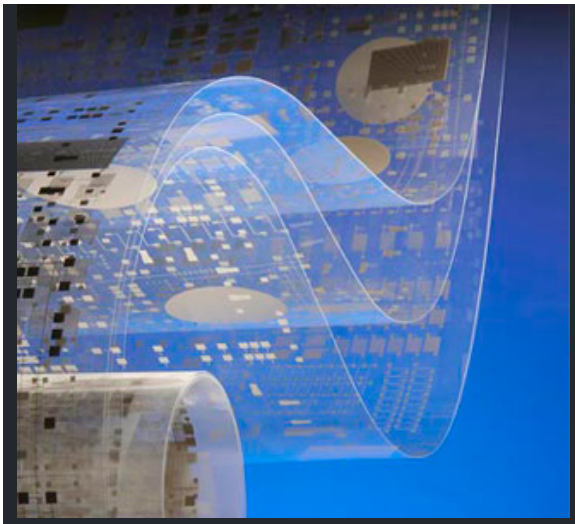
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Trisoft Graphics uses high-definition imaging, creating patterns down to 10 microns.

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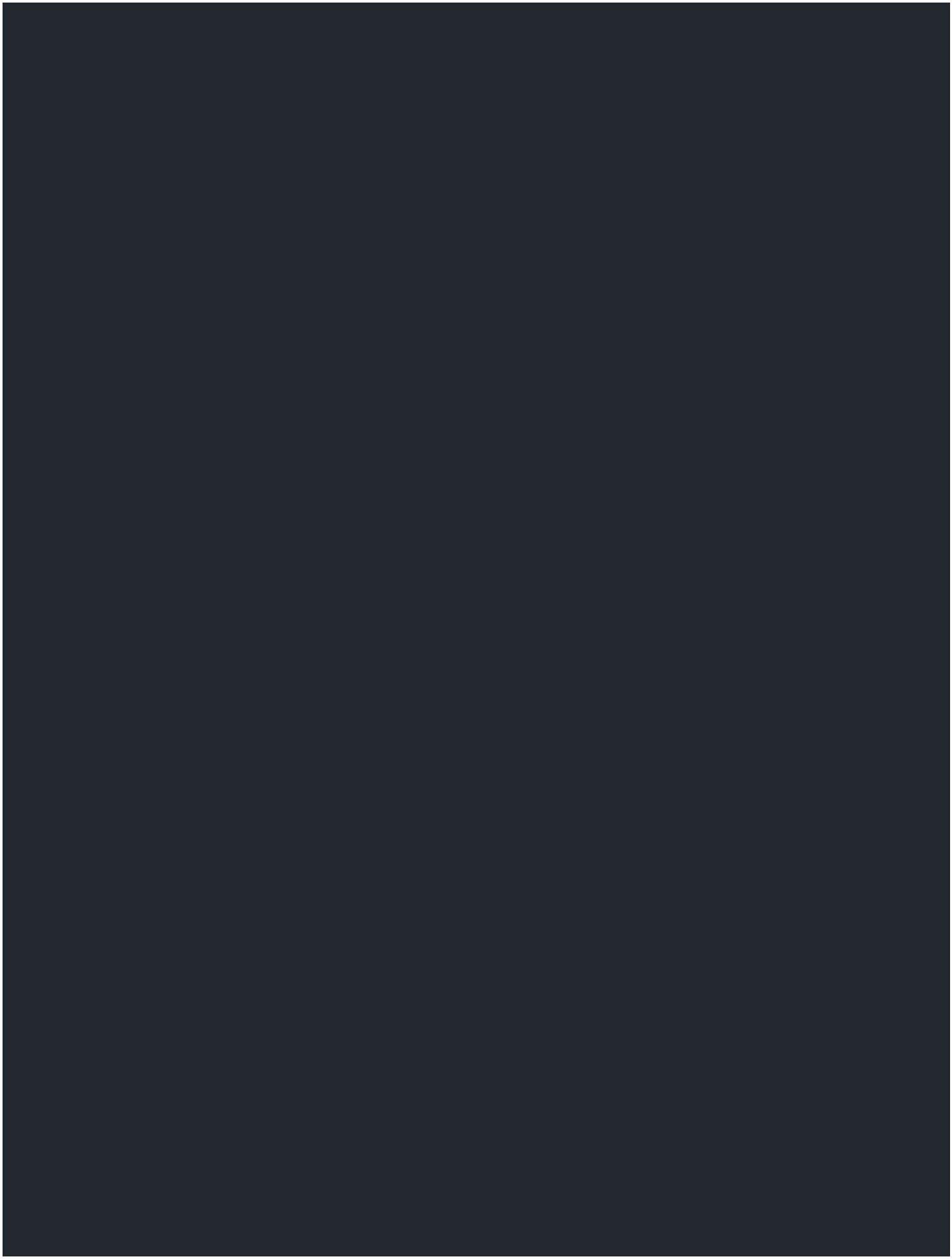
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Dual Band David Fractal Microstrip Patch Antenna for GSM and WiMAX Applications

Jacob Abraham, Thomaskutty Mathew

School of Technology and Applied Science, Mahatma Gandhi University Regional Centre, Kochi, India
Email: tjacobabra@gmail.com, mwrfgroupstas@gmail.com

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Abstract

The design and development of a proximity fed dualband microstrip patch antenna based on David fractal geometry are presented. David fractal microstrip antenna offers good performance in the 1.754 - 1.816 GHz and 3.37 - 3.415 GHz bands and is suitable for GSM 1800, WiMAX applications. The use of David fractal geometry offers miniaturization of the antenna structure. The proposed first iteration fractal configuration is fabricated and measured results along with simulation results are presented. Good radiation patterns and moderate gain are also obtained.

Keywords

Microstrip, David Fractal, Proximity Feed, Dualband

1. Introduction

Nowadays antennas with multi-band and smaller dimensions than conventional ones are preferred. Multiple resonances with good gain in a single patch are not directly attainable in simple microstrip antenna. Various techniques have been utilized in the antenna research to reduce size and to achieve multi-band characteristics in a single patch. A review of various techniques to minimize the antenna size is given in Ref. [1]. In [2] miniaturization of the patch antenna is obtained by combining two techniques, inserting slots as inductive loading and making some short point in the middle of the patch. In [3] a technique is proposed for reducing the size of a shorted microstrip patch antenna where notches are placed near the shorting pin and feed. And another technique is employed to achieve antenna size reduction by increasing the electrical length of the antenna [4]. Numerous research papers have reported for achieving dual band operation of microstrip antennas. A novel design of a dual band planar monopole antenna, consisting of a rectangular strip ring with double meander-lines and a top loaded vertical strip, is presented in [5]. In [6] slot antennas were used to achieve multiband characteristics. The conventional monopole CPW fed antenna with a U shaped strip and a pair of L slits in the ground plane to develop

multi-band antenna is presented in [7]. In [8] multi-band probe fed stacked patch antenna for global navigation satellite systems is reported which is intensively used both in civilian and military application.

Recently fractal techniques have been widely applied to antenna design to reduce the antenna size and to achieve multi-band behavior. Fractal antennas can be physically small but have electrically long lengths in small packages. Fractal geometry composed of multiple iterations of a single elementary shape, can be continued infinitely thus forming a shape within a finite boundary but of infinite length or area. This compactness in property is highly desirable in mobile wireless applications. The advantages of fractal antenna compared with a standard microstrip antenna are centered on miniaturization and bandwidth. Various geometries have been utilized to develop fractal antennas in order to have multi-band characteristics and miniaturization. Much intensive researches have been done in recent years to develop fractal antennas: long periodic fractal Koch antenna [9] and bow shaped fractal helix antenna [10]. A modified Minkowski fractal geometry for multiband operation is presented in [11]. Koch-like curve and Sierpinski Gasket are synchronized in a way, comprising so called Sierpinskized Koch-like sided bow-tie (SKLB) multi-fractal to achieve size reduction and multi-frequency use [12]. A plus shaped slotted fractal antenna with first and second iteration is reported in [13] that gives a good size reduction and enhanced band width.

Compared with the conventional square and circular patch antennas nowadays a lot of fractal antennas are developed with pentagon and hexagon shaped patches. A slotted grounded hexagonal microstrip antenna with a parasitic element is presented in [14]. Pentagonal shape for basic fractalization combined with inner sides etched with Koch fractal is reported [15] with achievement of good size reduction. A circular-hexagonal fractal antenna where iterations of a hexagonal slot inside a circular metallic patch is done to achieve multi-band behavior [16]. Another hexagonal fractal microstrip antenna where iterations of hexagonal slot inside a hexagonal patch with multi-band and broad band characteristics has been demonstrated in [17]. In [18] a CPW feed dual band fractal antenna structure is formed by inscribing a hexagonal slot within a circle.

The recent growth and rapid development of mobile communication systems and devices operating at multiple frequency bands have led to the requirement of antennas which support multi-band or wideband operation. Various wireless communication services have been available which may use frequency spectrum allocation like WiMAX/Wi-Fi etc. along with GSM communication system. This leads to development of multi-band antennas, where GSM mobile communication as well as WiMAX/Wi-Fi can be used simultaneously. Various research papers have reported about dual band antennas that are suitable for above mentioned application [19] [20]. The WiMAX standard has the advantage of allowing wireless connection between a base transceiver station and thousands of subscribers without requiring the subscriber to be in a direct line of sight with the station, called non line of sight communication [NLOS]. This gives users the mobility to move around within a broad coverage area and still be connected to the network, to provide high speed internet access. The advantage of multi-band antenna is the ability to integrate several frequency bands on one single antenna, making it useful for several frequency ranges.

In this paper, a novel hexagonal fractal microstrip antenna is proposed for multi-band applications. David fractal [21] concept is introduced into a hexagon shaped microstrip patch antenna to obtain multi-band behavior and miniaturization. This hexagon shaped dual band David fractal microstrip patch antenna resonates at 1.8 GHz and 3.4 GHz. The first frequency is used for GSM cellular communication and the second frequency is used for WiMAX applications. In order to obtain antenna, with optimized parameters, simulation studies were carried out using CST microwave studio. In the proposed antenna, at upper resonance frequency the maximum power received will be at 43˚ away from the bore sight, and these characteristics may find applications in non-line of sight communication including WiMAX [22].

2. David Fractal Geometry

The fractal design of antennas results from the blend of two discipline, electromagnetic theory and fractal geometry. The term fractal and fractal dimensions were coined by B. Mandelbrot [23]. Mandelbrot defined a fractal as a rough or fragmented geometric shape that can be subdivided in parts each of which is a reduced copy of the whole. The David fractal is a class of fractal geometries whose recursive procedure is demonstrated in **Figure 1**. The David fractal pattern is formed from the basic hexagon shaped patch or the initiator as in **Figure 1(a)** by dividing it in to six smaller hexagons, six equilateral triangles and a David star at the center; the triangles and the star are removed. It results in first iteration level as shown in **Figure 1(b)**. The second iteration as shown in

Figure 1(c) is a reduced copy of the design of the first iteration repeated in each smaller hexagon. From the iteration stages it is observed that at the end of the first iteration stage six smaller hexagons with equal dimensions are produced and at the end of the second iteration stage thirty six further smaller hexagons are produced. The six hexagons of the first iteration stage are fractalized in to thirty six hexagons.

3. Antenna Configuration

The antenna is fabricated onan FR-4 substrate of thickness 1.6 mm with relative permittivity of 4.4 and loss tangent of 0.002. The zeroth iterated level antenna consists of a hexagonal patch, with each side of the patch having a length of 24.6 mm, resonating at 1.8 GHz called the initiator as shown in the **Figure 1(a)**. In this antenna proximity feeding technique is employed. The antenna is fed by 50 ohm microstrip feed line with a width of 3.03 mm and length of 31 mm. In order to achieve multiband characteristics David fractal geometry is introduced in to the hexagon shaped patch. **Figure 2** illustrates the structure of the proposed dual band miniaturized David fractal first iteration level antenna. The fabricated prototype of the David fractal antenna is shown in **Figure 3**. The return loss variations with frequency of the first iterated level David fractal antenna shows dual band characteristics. It has two resonant frequencies at 1.55 GHz and 2.64 GHz. The dual band antenna is optimized so that the simulated David fractal antenna produces two resonances at 1.8 GHz and 3.4 GHz. The lower resonant frequency is suitable for GSM mobile communication and the upper resonant can be used for WiMAX applications in 4 G phones, which is used to provide high speed internet access for non-line of sight environments. In this case resonant frequency optimization is done where optimization parameter is the side length of the hexagonal patch antenna. The detailed dimensions of the antenna are shown in **Table 1**. The design of the antenna was optimized using CST Microwave Studio Suit 2010.

4. Measurement Set-Up

The measurements were carried out in an anechoic chamber using HP 8510C Network Analyzer. The chamber was arranged such that the source remains stationary as the antenna under test (AUT) rotates. A standard horn antenna is used as the reference antenna for the measurements. The antenna under test is placed in an antenna

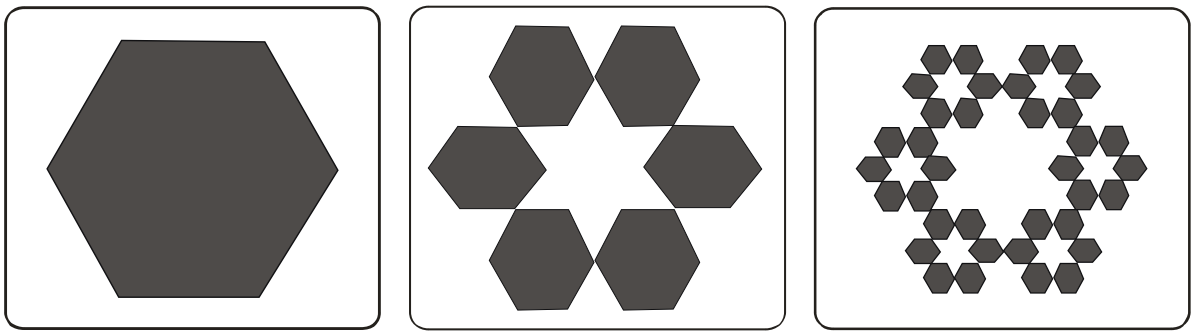


Figure 1. Different iteration stages of David fractal.

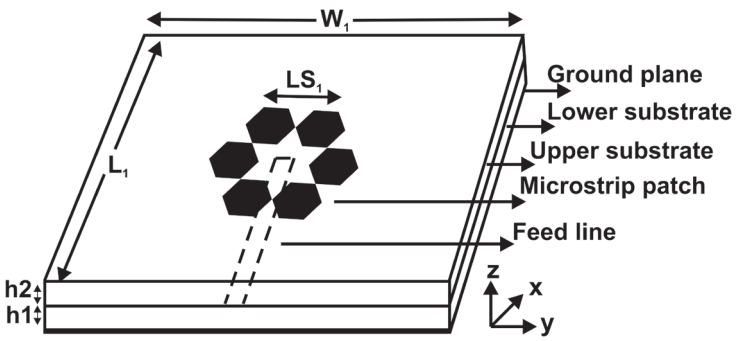
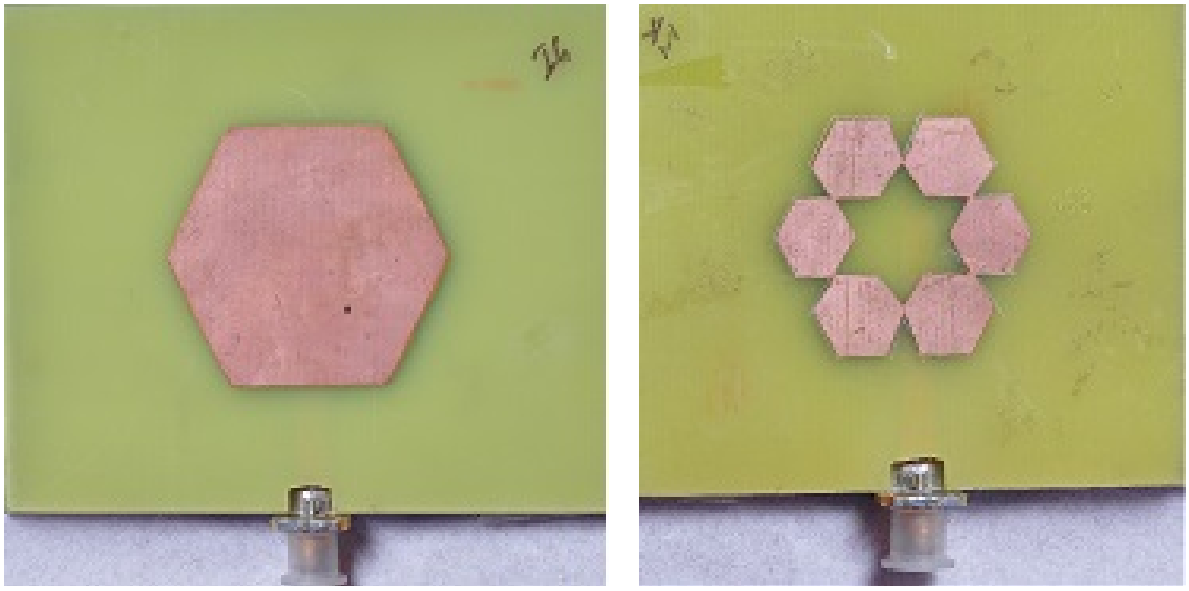


Figure 2. Structure of the proposed dual band fractal antenna.



(a) (b)

Figure 3. Photograph of the fabricated antenna: (a) Zeroth iteration level David fractal antenna; (b) First iteration level David fractal antenna.

Table 1. Dimensions of the dual band fractal antenna (units: mm).

Parameter	Value	Parameter	Value	Parameter	Value
L_1	72	W_1	84	LS_1	21.4

holder, which is set to rotate the antenna in small steps of 1˚ to obtain a 360˚ radiation pattern. The microwave materials that covers the wall, top and bottom surfaces absorbs electromagnetic energy so that the anechoic chamber to replicates a space equivalent.

5. Results and Discussions

Figure 4 shows the simulated and measured return loss variation with frequency for the 1st level iterated David fractal hexagon patch antenna. It can be seen that the −10 dB bandwidth for the measured return loss is 62 MHz (1.754 - 1.816 GHz) and 45 MHz (3.37 - 3.415 GHz) respectively, which can cover GSM mobile communication system and WiMAX applications in the 4 G mobile phones. **Table 2** shows comparison between simulated and measured antenna parameters for the first iterated level David fractal microstrip patch antenna. The discrepancy between the measured and simulated results is due to fabrication tolerance and small air gap between dielectric layers.

Figure 5 illustrates the simulated surface current distribution on the antenna at the two operating frequencies. At lower resonant frequency current density is concentrated along the inner region of the radiating patch and for the upper resonant frequency; the current density is concentrated along the outer regions of the radiating patch while small amount of current is flowing at the inner areas of the patch.

The co-polar and cross polar radiation patterns have been measured at two different frequencies of 1.79 GHz and 3.385 GHz for both E and H plane. The radiation pattern data are normalized in order to plot the co-polar and cross polar patterns in one graph. The measured far field radiation patterns of the dual band David fractal first level iterated antenna in the E plane (y-z plane) and H plane (x-z plane) are plotted at the frequency of 1.79 GHz and 3.385 GHz is shown in **Figure 6** and **Figure 7** respectively. At the lower resonance frequency (1.79 GHz) the maximum power was received by the antenna at the bore sight direction while at the upper resonance frequency (3.385 GHz) the maximum power was received at angle 43˚ with respect to bore sight. The upper band characteristics are suitable in non-line of sight applications.

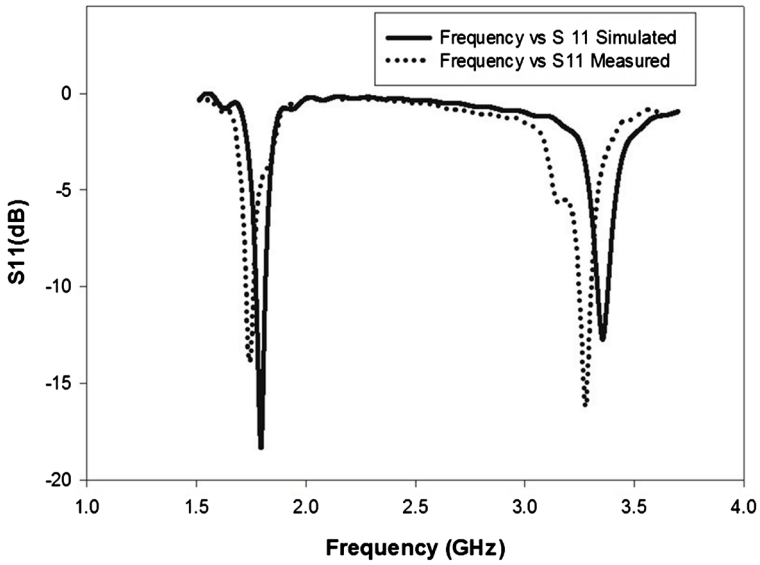
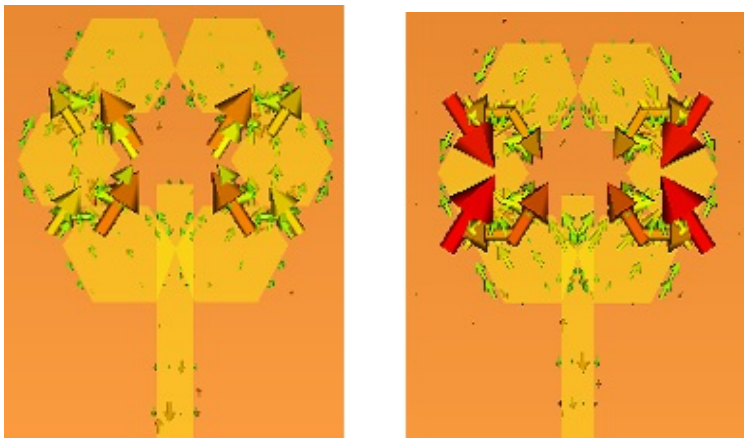


Figure 4. Measured and simulated return loss for the proposed antenna.

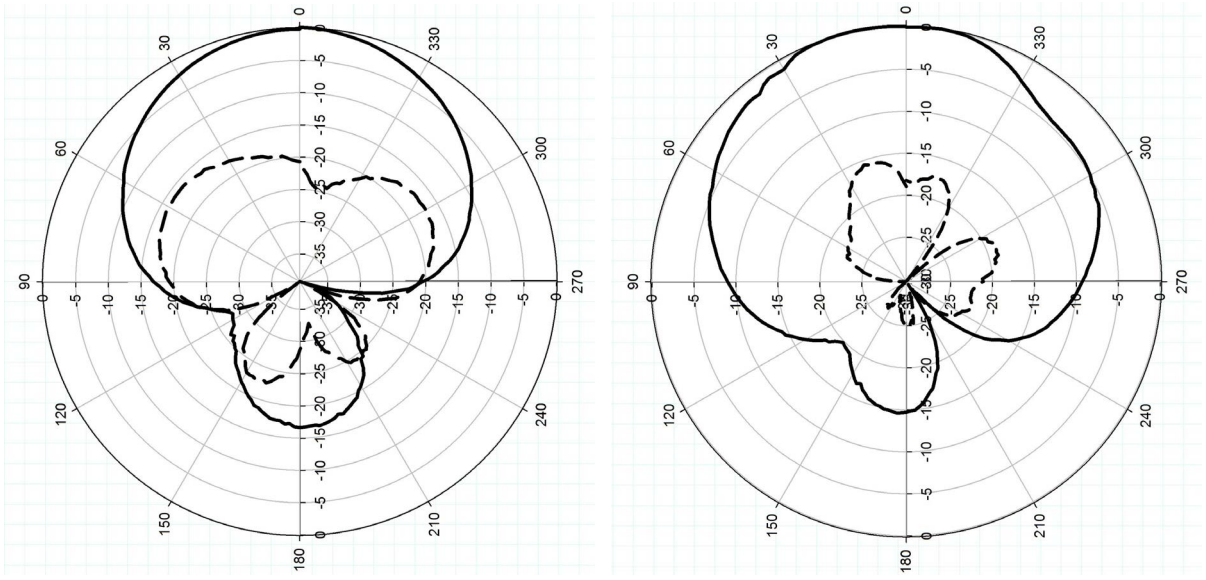


(a) (b)

Figure 5. Simulated surface current distributions on the radiating path for the proposed antenna at (a) first resonance frequency 1.8 GHz and (b) second resonance frequency 3.4 GHz.

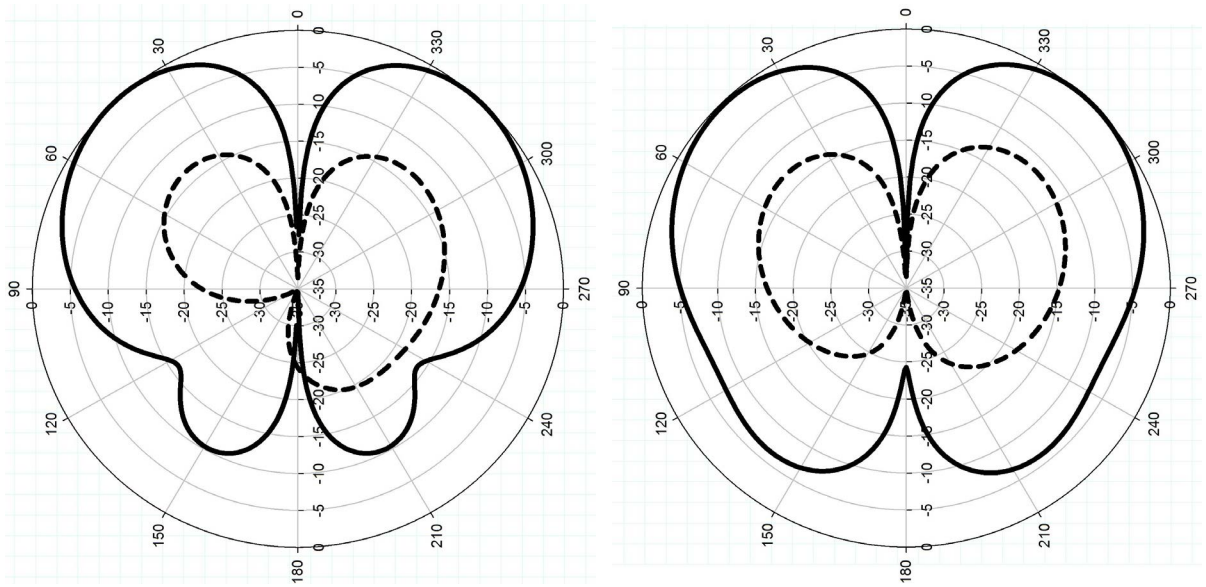
Table 2. Simulated and measured results.

Parameter	Simulated	Measured
Resonance frequency f_1 (GHz)	1.8	1.79
Bandwidth$_1$ (MHz)	55	62
S_{11} (dB)	−18.7	−13.54
Gain (dBi)	6.93	6.5
Resonance frequency f_2 (GHz)	3.4	3.385
Bandwidth$_2$ (MHz)	31	45
S_{11} (dB)	−14.3	−16.48
Gain (dBi)	5.3	4.9



(a) (b)

Figure 6. Measured normalized radiation patterns of the antenna at resonant frequency 1.79 GHz. (a) E plane; (b) H plane (co-polarized, _____solid line and cross polarized, ……dashed line. (a) y-z plane; (b) x-z plane.



(a) (b)

Figure 7. Measured normalized radiation patterns of the antenna at resonant frequency 3.385 GHz. (a) E plane; (b) H plane (co-polarized, _____solid line and cross polarized, ……dashed line. (a) y-z plane; (b) x-z plane.

The measured gain of the antenna is 6.5 dBi at the lower resonant frequency and 4.9 dBi at the upper resonant frequency. The upper band characteristics will find useful in the non-line of sight applications including Wi-MAX. It is also observed that size reduction up to 18.3% in terms of overall size and 23.4 % in terms of the copper cladding is obtained in comparison with a hexagon patch microstrip antenna resonating in the first resonant frequency band.

6. Conclusion

The proposed hexagon shaped David fractal microstrip patch antenna has demonstrated its potential for mul-

ti-band operation. The antenna generates two resonating modes centered at the measured frequencies of 1.79 and 3.385 GHz; the first band finds application in GSM mobile phone communication and the second band finds application in WiMAX. The proposed multi-band antenna provides moderate gain and good radiation characteristics.

Acknowledgements

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The Farnsworth Television and Radio BT-58 Radio Project

A comprehensive story containing historical, educational, technical and biographical elements & opinions

by

John Fuhring



A very rare picture of a surviving Farnsworth BT-58 portable radio
showing what they actually looked like.
image used by permission

Introduction

This is the story of a rare Farnsworth radio that a friend and I collaborated on to bring back to life. It started life as a portable radio that could be operated off an internal battery pack or by plugging it into the AC line and in that regard, it is similar to my 1942 Philco portable radio (written about elsewhere on my website). This radio is special because it was made by the Farnsworth Radio and Television Company around 1942 just before the government stopped all commercial radio manufacturing and sales.

Before continuing, I'd like to say something about the man who owned the company that made this radio, Philo Farnsworth. He is the forgotten inventor of electronic television and many other brilliant inventions that are beyond the scope of this little story. Farnsworth's life is well worth looking into for the lessons it teaches about how technical brilliance and genius is not enough to be a success in the world of American Business. Indeed, geniuses like Farnsworth and Armstrong are universally exploited by ruthless business people who's only talents are their ability to manipulate the legal and financial systems and in their ambition to wealth, they think nothing of ruining the very people who make their wealth and business success possible.

Unlike the Troy Radio and Television Company (one of their radios I also write about on this website), the Farnsworth Television and Radio Company survived long enough to actually produce television sets during the early 1950s, but they didn't last very long once the big corporations dominated the industry. It came as a bit of a surprise to me to learn that people were watching television sets as early as the mid-1930s and indeed the 1936 Berlin Olympics were broadcast on German TV. In those early days, the so-called NTSC standard had not been formulated and Armstrong's FM system was not used to carry the sound. The sound for the early TV sets was carried on ordinary AM radio so that a viewer needed to have a TV set for watching the picture and a AM radio - like this one - for listening to the sound. It wasn't until after World War Two that FM sound was put on to the television signal and TV sets had their own audio receiver. This then is the story of a radio that was made by a television company founded by a brilliant television pioneer and a radio that could be used on a picnic (with its batteries) or at home on AC current. It could be used to listen to all the wonderful entertainment, music and news of its era or it could be used to produce the sound of some of the very first television programs.

My Farnsworth radio

For as brilliant as Philo Farnsworth was and as advanced and innovative as his work in electronics was, this particular radio is of a very conventional design and there is absolutely nothing innovative about it. Basically it uses the very same design features as the radios of the early 1930s, but it was and is a nice radio that works as well as any in its class. I have no idea how many of these radios were made, but probably very few as there are no pictures of this model or anything like it

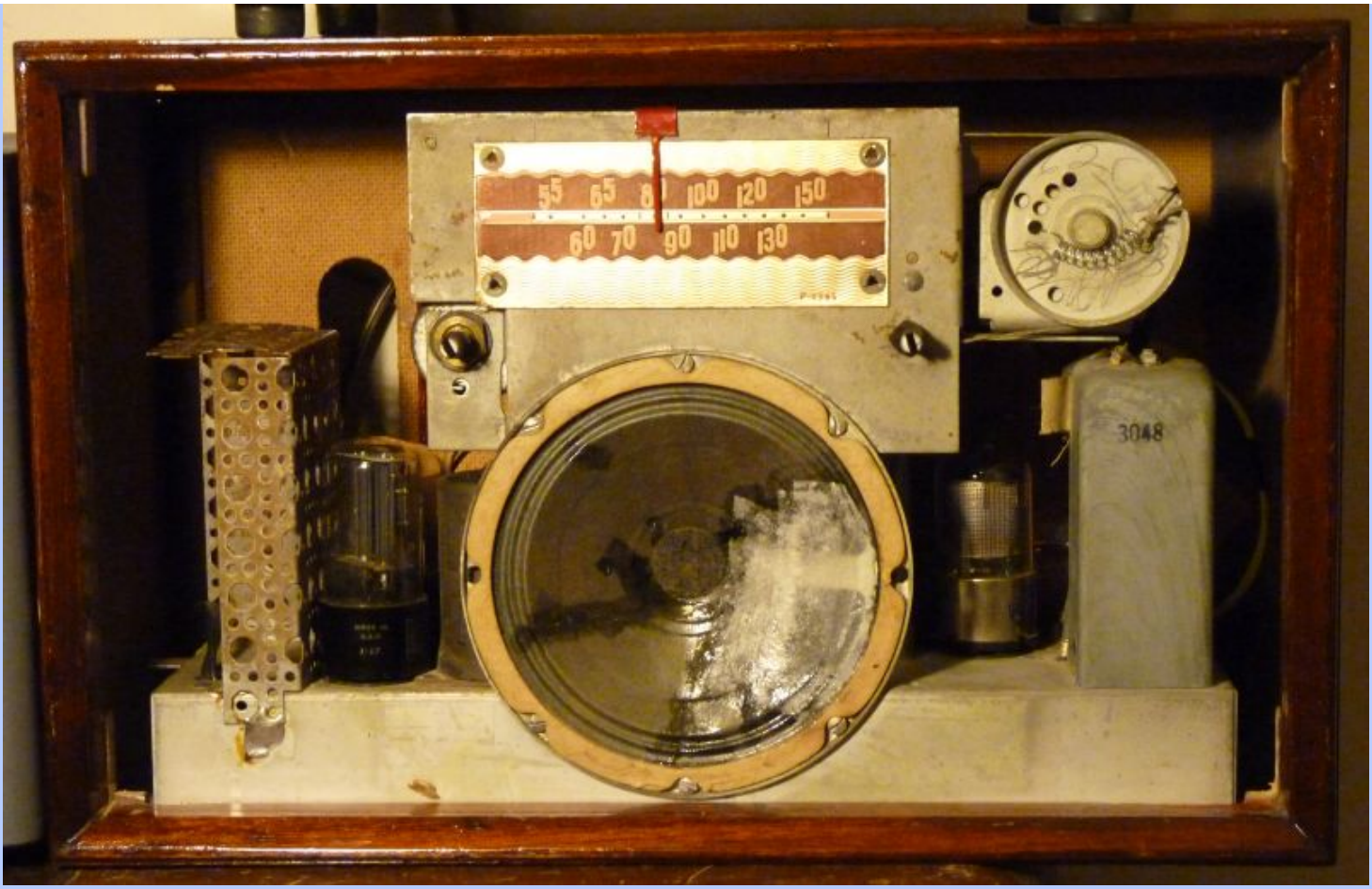
anywhere on the Internet.

By the way, there are a couple of things that are slightly unusual about how this radio was constructed. All the resistors are an unusual wire wound type instead of the much cheaper carbon type and all the parts that are bolted and screwed on have inspection stripes indicating a level of quality control usually only found on military equipment. Perhaps the factory had earlier had a quality control problem and so the managers brought in QC inspectors to make sure the products were of the highest quality construction, but that is just a speculation.

This then is the story of how I got my Farnsworth Model BT-58 radio and how I restored it.



How the radio looks today. The case is not original, but made out of a wooden speaker cabinet that fits the chassis perfectly as if it were made for it. The front panel is stained wood with period knobs. The big 'F' that makes the opening of the speaker was cut out by me in honor of Philo Farnsworth, the forgotten genius.



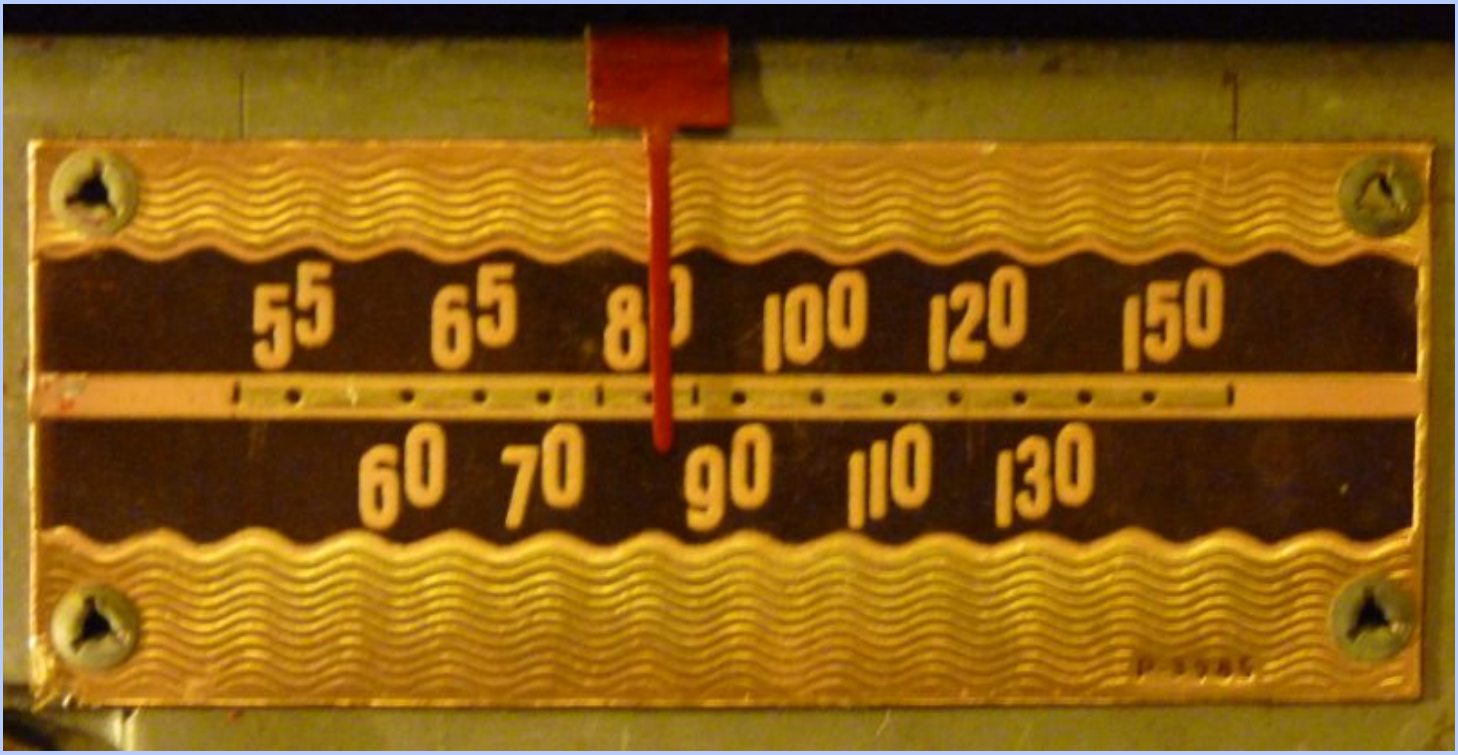
The front view of the BT-58 chassis. Note the heavily damaged speaker that I rebuilt.



The rear of the BT-58 chassis showing the old fashioned tubes with their grid caps. The unterminated wires in the center would go to a 1.5 volt 'A' battery and a 90 volt 'B' battery if they were plugged in otherwise it operates on 120 volts AC. Lacking any official nameplates and identification, I penciled in the make and model and my own name on the back of the chassis.

The radio when I first acquired it

This radio project began with a bare chassis and no outer case. The dial pointer (the red object below) and the loop antenna (making up the input RF tuned circuit) were also missing. The chassis was owned for decades by my friend David Dodd, but the outer case was lost so long ago nobody now remembers what happened to it or even what it looked like. To make matters complicated, there were no brand names or any other identifying marks on the chassis or any sub-assembly and I had no idea who made it or where to start to look for a schematic diagram. I did notice that the front dial was very unusual and I'd never seen anything quite like it. It was the dial that I used as a clue to track down the maker of the radio.

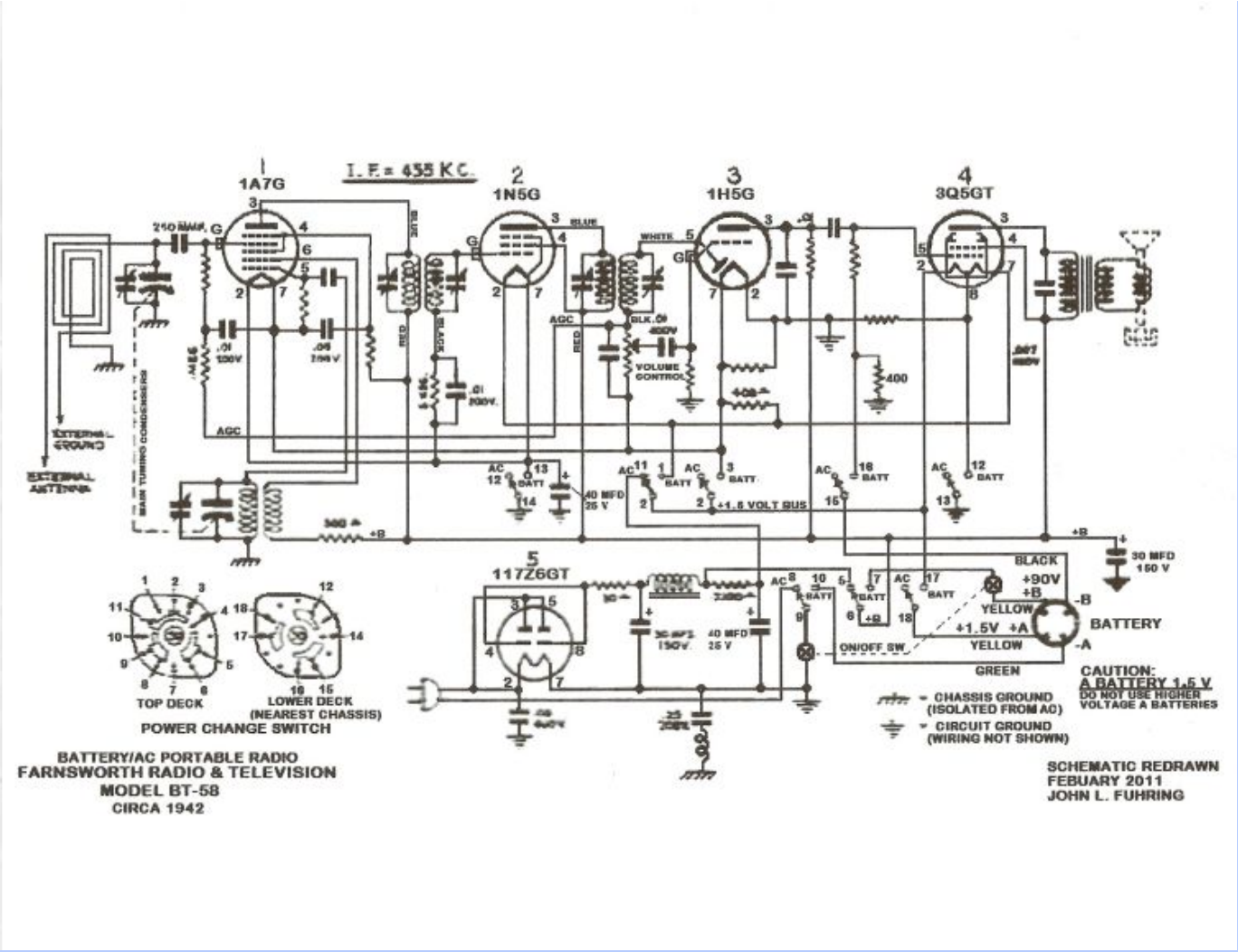


An unusual looking tuning dial.
Isn't that a really good looking red pointer?

Identifying the maker and the model of the radio

Thanks to the wonders of the Internet, I was able to look over dozens and dozens of pictures of old radios dating back to about when I guessed this radio must have been made (1938-1948). On a German antique radio site I found a radio with an identical dial and it was identified as a Farnsworth Television and Radio Company, BT-68 radio. I was very pleased with my discovery and then went to another really fantastic site to download the schematic. The first thing I noticed was that the schematic was very similar to the wiring of my radio and it used the same tube set, indicating that it was indeed a Farnsworth radio, but it was not exactly the same because it called for an extra RF amplifier tube that my chassis didn't have. That got me searching more and I found reference to a 1942 Farnsworth BT-58 radio, but because it was probably a very rare radio, there were no pictures of it - anywhere - and that is probably because there are none that have survived to this day. When I downloaded the schematic diagram and carefully looked it over, bingo, I had my radio exactly and right down to the last wire. I indeed had a model BT-58 Farnsworth radio.

Redrawn and usable schematic of my radio



Thanks to the Internet, the schematic of even this very rare Farnsworth BT-58 radio is available. The original image I captured was hard to read and follow (especially the switching between battery and AC operation), so I completely redrew the schematic on my PC by using the Paint program and now I have a superior schematic.

Restoring the old radio to operation

Except for the dial pointer, the loop antenna and the outer case, the radio was all there, however, the old beeswax covered paper capacitors were in very bad condition and naturally they and the electrolytic capacitors would have to be replaced. Modern replacement parts are available locally and are pretty cheap, so I began to take all the capacitors out and replace them with modern disk ceramic and miniature electrolytic versions. With the help of my revised and readable schematic, this took a couple of hours, but it was a rather simple task. I also had to replace some of the original wiring as the rubber insulation had fallen apart and that took some time too. I think I spent all of about $15 on this radio.

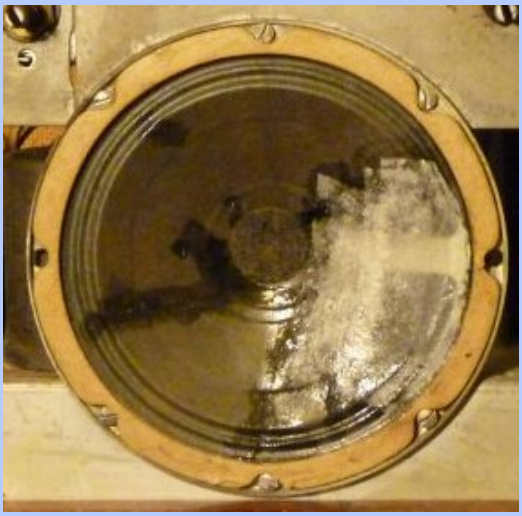
While I was at it, I traced down all the wires going to the 'A' and 'B' batterys and discovered that whoever had labeled them a long time ago had things all wrong. If anybody would have connected up a 7.5 volt battery to the 'A' battery (instead of a 1.5 volt battery), they would have instantly burned out all the tube filaments and destroyed the radio. As luck would have it, nobody had ever done that and all the tubes still work perfectly. Going through the radio and the schematic wire by wire I discovered a few mistakes somebody had made when they drew up the original diagram, but they were easy to find and correct.

There were two things that I was afraid might be show-stoppers with regard to getting this radio restored. First was the missing dial pointer. I didn't know where I'd be able to get another one of those, but then it dawned on me that I could make one myself. I took a strip of broken hacksaw blade and I heated it to red hot on my stove and then let it cool slowly to anneal it. Doing so made the steel very easy to shape so the top of it would fit in its guide and very easy to file the bottom of it into a pointer shape. I was really pleased how nicely the metal bent into the complex shape I needed and easily it was to file the metal away to form a pointer. After I had the steel pointer formed and shaped, I painted the thing with red fingernail paint to match the original red dial pointers I had seen in pictures. I installed the pointer and once in, I was pleased at how good it looked and how smoothly it worked as I rotated the tuning control.

The more serious looking problem was the heavily damaged speaker. About a quarter of the speaker cone was missing and the rest of it was torn and cracked. The speaker frame formed an important part of the structure of the radio and supported the tuning deck and the on/off/volume control so I couldn't just remove it and replace it with a modern speaker. I considered taking the "guts" out of the speaker frame and putting a smaller and thinner speaker in, but thought I'd wait and try an experiment first.

After I had all the new parts in the radio and after I had carefully checked all the wiring against the schematic diagram, I plugged in the power cord and turned on the radio. After a long warm-up, characteristic of tube radios, the radio came to life. I felt some surprise that all the old tubes still worked after being silent for over 50 years. What really surprised me was the good sound that came out, loud and clear, from the heavily damaged speaker. This was really unexpected because over a quarter of the speaker was gone and I expected it to rattle and be highly distorted.

Rather than replace the existing speaker with a smaller one, I decided to try to rebuild the speaker cone. First, I doped up all the cracks and tears in the speaker until I had the remaining 3/4s of it looking good. It occurred to me that I could replace the missing portion of the speaker if I would build it up out of multiple strips of tissue paper impregnated with a doping material. For a suitable light tissue I used, of all things, long, narrow strips of single layer toilet paper and for dope I used clear fingernail polish since I figured it would be tough and long lasting. I started by gluing down a strip, then I'd impregnate it with dope, lay down another strip, dope it, another strip, dope it and pretty soon I had the missing portion of the speaker cone completely rebuilt with a light, but rigid material that I hoped would match the characteristics of the rest of the speaker cone. After the dope had hardened and everything looked good, I turned on the radio. I was absurdly pleased with my little self because the rebuilt speaker sounded just great with no rattle or distortion and plenty of volume coming out of it. This was one time when one of my crack-pot ideas actually worked and worked well.



Rebuilt speaker after filling in with
doped toilet paper strips.

Placing it in a period style cabinet and final assembly

In the meantime, my friend David took some old speakers out of an old cabinet, cut out a blank sheet of plywood for a front panel and gave me the pieces. I took the blank panel and cut out an opening for the dial and the control knobs and then carved an 'F' (for Farnsworth) into the opening for the speaker. I rather doubt that the original radio looked like this, but I have done my best to recreate something period. I have no idea what the original cabinet for this radio really looked like because this model is so rare that no pictures are to be found on the Internet.

Another critical part that was missing was the original tuned loop antenna. I bought some nylon standoffs and mounted them on the back panel to wind the coil on and then calculated about how many turns I'd need to tune in the broadcast band. I wound the coil with number 30 wire and then proceeded to fine tune the circuit. I found that I had placed way too many turns on the form, but I finally removed enough winding that the radio's "front end" was tuned in properly and now I can listen to KGO up in San Francisco (250 miles away) an night loud and clear on this radio.

From a historical stand point, I am glad I own this radio and it is kind of fun to think that perhaps I own the only surviving example of this model radio in the known universe, but gee whiz, what am I going to do with another AM radio, even one that can be operated portable on its own batteries? Right now I have it in the the nicest bedroom of my house that I use as a guest room on an antique "secretary's desk" and it really looks nice there and really adds to the decor of the

bedroom.

This just added.

As of yesterday (May 31st, 2012), I became aware of the existence of another BT-58 radio (see picture at the beginning of this story). To the best of my knowledge, this is the only complete radio of this model number in existence and it would be wonderful if the radio could be fully restored and put back in working condition.

You know, when we think of World War Two, we usually think of battles and other military operations. In fact, life in the United States went on and people at home lived their lives as best they could and tried to be as happy as they could be. Having a portable radio and taking it with them to picnics, to the beach or to parties added to the pleasure people felt while doing such things. The batteries were very expensive and they didn't last very long and they were probably very difficult to get while the war was on, but the expense of owning and operating a wonderful little device like this was well worth it because of the entertainment and pleasant ambiance they provided.

There are a lot of historically important artifacts dating from the World War Two era, but most of them are of a military nature. Military artifacts remind the collector of how the war was executed, but I think we should remember that there was also a vitally important "home front" during the war too. In my mind, portable radios such as this one are precious artifacts that should remind us of the very important civilian side of the war. I sincerely believe that these radios are a very poignant snapshot into the lives of the parents, wives, sisters and younger brothers who had to endure the war while their sons, husbands and brothers, the soldiers and sailors, were away fighting, suffering and being killed. I think these kinds of artifacts tangibly remind us of everyday civilian life and make us realize that while the soldiers and sailors were enduring what they were forced to endure, they were also looking forward to the time when they too could return to the pleasures of home. Going on picnics on Sunday or to the beach and taking a portable radio with them so they could listen to ball games and popular music was certainly part of the "good life" they were looking forward to.

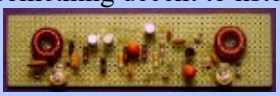
THE END

Having arrived this far, obviously you have a superior attention span and reading ability that far exceeds that of the majority of web users. I highly value the opinion of people such as yourself, so I ask you to briefly tell me:

Did you enjoy this article or did it suck?

Please visit my guest book and tell me before you leave my website.

If you have an antique AM radio and you need something decent to listen to, perhaps you should buy or build your own



Low Power AM transmitter

If you liked this story, perhaps you would like to read about another portable radio from this era

My Summer for '42 Philco portable radio

Or perhaps you'd like to read about my rare

Troy Radio and Television Company Art Deco radio

I have several other articles on old radios including a beautiful Fairbanks Morse that you might be interested in



Please select another radio article

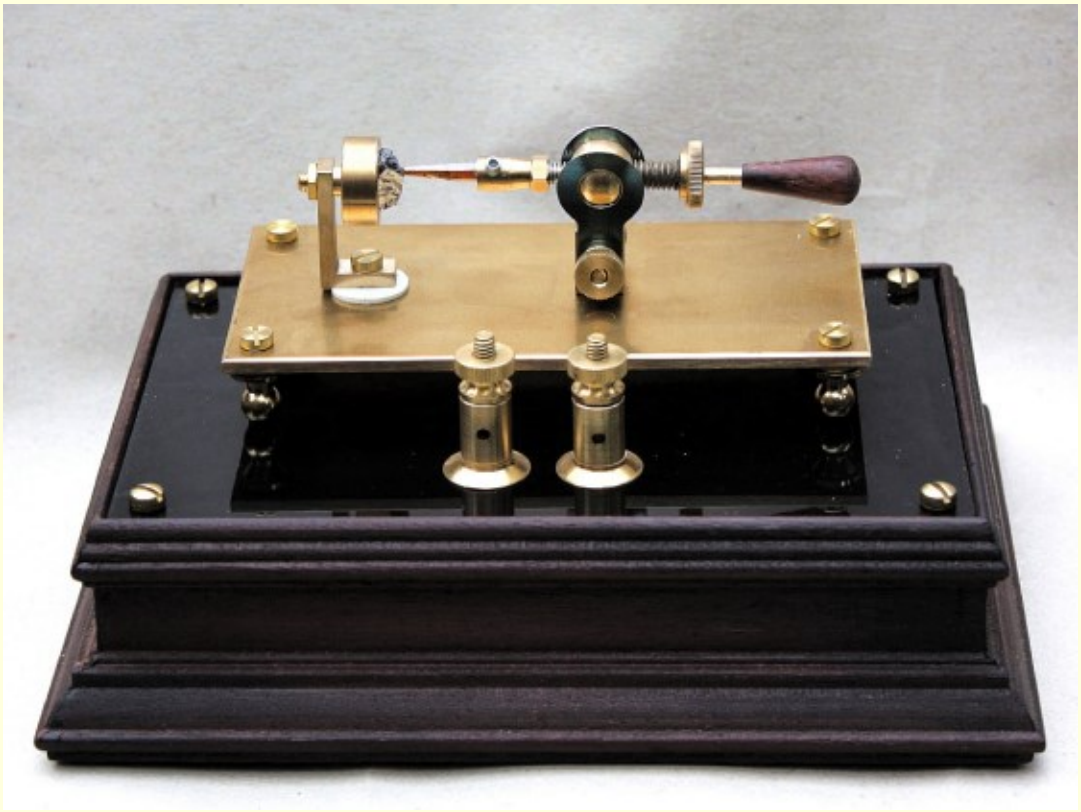
Return to my Home Page



Home

Detector Stands and Crystals

PERIKON DETECTOR No1



This was made for Alan Reeves for his Westinghouse Crystal Receiver which was missing the detector. I mounted the finished detector on a base as I originally intended this to be used with other crystal receivers.I have fitted a Galena and Zincite Crystal to this but many combinations of crystals can be used.

It is essential to make a good electrical contact to the Zincite I used a very thin strip of sheet pewter which is a very soft metal and cushions the contact with the rather delicate Zincite.The whole crystal is held in place with a grub screw.

The Galena is held in place with 'Woods metal' another very soft metal alloy which melts at a lower temperature than Lead and Galena.

The two crystals are held in point contact by a spring loaded shaft and the pressure is adjustable with the Knurled screw.It is possible to rotate the crystals and move up and down and side to side on the crystal surfaces in a similar way to a Catswisker.

The Dark Oak stained box measure 6 inches x 4 inches The size of the detector was a bit of a challenge to make on my old lathe but i really enjoyed it.

Im looking forward to the next one of these projects as I find these devises very interesting. If research had continued on these instead of the thermionic valve we may have had the transistor in the 1920's.and computers by the 30's

Close Up View



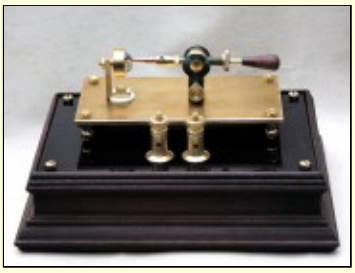
GALENA CRYSTAL HOLDER with fixing screws, insulators and solder tag also including a small piece of Galena (Lead Sulphide). The holder is ½ inch/12.5mm diameter and 3/8 inch/10mm deep. Suitable for woods metal or grub screw securing of crystal.Larger View Included Hardware

P/N
01-001
£5.99 Ea.



CATSWHISKER DETECTOR with galena crystal. I made this in my workshop from Solid Brass Turned parts and finest Rosewood. The detector has a solid gold wire 'Catswhisker'used to tickle the crystal until you find the best reception. It works great with a little patience. Larger View

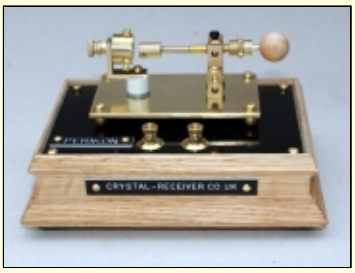
P/N
30-001
£50.00 Ea.



PERIKON DETECTOR No1 The description is shown above.

Larger View Close Up View

P/N
30-002
£100.00



PERIKON DETECTOR No2 The description will be added soon

Larger View

P/N
30-003
£100.00



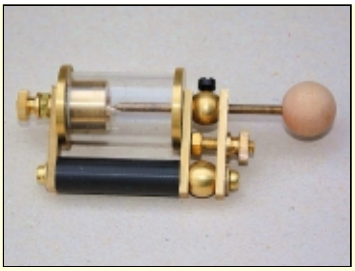
VERTICAL MOUNTED PERIKON DETECTOR No1 This detector holds two crystals in point contact in a clear tube. It has a knurled screw on top for fine adjustment of pressure.

Larger View

P/N
30-004
£50.00

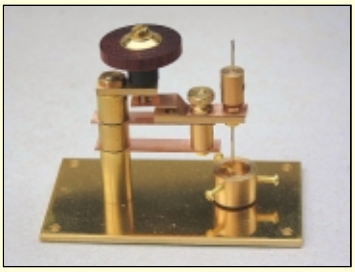
ENCLOSED TICKLER DETECTOR #1

P/N



Larger View

30-005
£ POA



CLAPP EASTHAM TYPE

Larger View

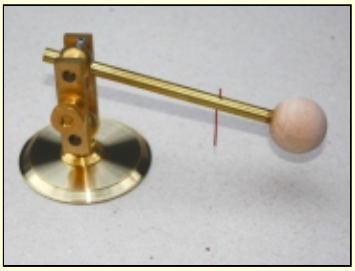
P/N
30-006
£ POA



COHERER No1

Larger View

P/N
30-007
£ POA



FRENCH STYLE DETECTOR

Larger View

P/N
30-008
£ POA



GEOFF JAM JAR DETECTOR No1

Larger View

P/N
30-009
£ POA



GERMANIUM TICKLER DETECTOR

Larger View

P/N
30-010
£ POA

CRYSTALS

GALENA CRYSTAL Small Crystal approx 1/2 inch x 1/4 inch P/N



or 12.5mm x 6mm. Larger view. Please enquire for prices and availability.

10-014
£x.xx Ea.



FOOLS GOLD (Iron Pyrite) Approx 1/2inch x1/2 inch or 12.5mm x 12.5mm Larger view. Please enquire for prices and availability.

P/N
10-015
£x.xx Ea.



IRON PYRITE CUBE Near Perfect Cube. 1/2 x 1/2 x 1/2 or 12.5 sq Larger view. Please enquire for prices and availability.

P/N
10-016
£x.xx Ea.



PEACOCK ORE Approx 3/4 x 3/4 or 20 x20 mm Larger view. Please enquire for prices and availability.

P/N
10-017
£x.xx Ea.



RED ZINCITE Approx 20mm Long Larger view. Please enquire for prices and availability.

P/N
10-018
£x.xx Ea.



SILICON METAL Pure Silicon metal element. Size is approx 1/4x1/4x5/16 inches.6mm x 6mm x 8mm. Larger view.

P/N
10-019
£x.xx Ea.



GERMANIUM METAL Pure germanium metal crystal.size approx 1/4 x 1/4 x 5/16 or 6mm x 6mm x 8mm. Other sizes available on request Larger view. Please enquire for prices and availability.

P/N
10-020
£x.xx Ea.



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GP PATCH ANTENNA (Goof-Proof Patch)

Building a high performance Patch Antenna may seem like a daunting task. But assembling your own is actually quite easy and these instructions make it nearly goof-proof. This Patch will outperform commercially made versions that use lower efficiency circuit board construction.

Introduction

It is no secrete that the most important component in your wireless video system is the antenna. While most folks are investing in more powerful transmitters, you can obtain additional range merely by concentrating your efforts on the antennas that are used. For sure, in our R/C wireless camera application, where the transmitter is a moving target, antenna choices require some care during the selection process.

Antennas come in many flavors, but the ones that are supplied with most imported "sardine can" video systems are dipoles and vertical whips. These are considered to be omni directional antennas and are fine for basic consumer applications. And although there are better choices, they have been used with good success on the transmitter end of an airborne R/C video system. However, these omni antennas are the system's achille's heel when they are used on the ground based receiver.

I have found that a higher gain antenna with a reduced *beamwidth* is best for use on the receiver's end. The extra gain extends your range and limiting the beamwidth helps reduce multi-path interference and minimizes the capture of extraneous signal sources (the 2.4GHz band is full of consumer RF devices).

And in order for mortals like me to build it, home brew antenna projects must be very simple and nearly goof proof. Better still, step-by-step instructions would be nice to have. Up until now, that laundry list of requirements seemed like an very tall order. But not any longer, as you will soon see.

A Patch is Hatched

Since I experienced good results with commercially purchased Patch antennas, I decided to concentrate my efforts on documenting a 2.4GHz (13cm) ham band Patch that others could build for themselves. My goal was to present a set of plans that nearly any opposing thumb equipped mammal could understand (some lower primates excluded) and present the information in such a way that success would be nearly guaranteed.

The Patch antenna shown here is a good performer when used on a 2.4GHz video receiver. It has more gain (estimated at nearly 3dB higher) than my battle worn X10 Patch. Depending on the exact frequency used, gain is estimated to be from +5dBi to +8dBi. The antenna is linear polarized. Beamwidth is broad enough so that antenna aiming is minimized.

I recommend the GP Patch (Goof Proof Patch) to anyone that is experiencing poor results using simpler antennas, such as a factory supplied vertical whip. It is easy and cheap to build, so there is really no down side to trying it out. If you suspect that your antenna is not up to par then give this one a try.

What you will find here is a design that requires basic hand tools to build. The materials are commonly found and there is enough flexibility in their choice that obtaining them should be uneventful. In addition, full scale templates (available as a free download) are provided that allow you to accurately cut out the parts.

If your video system operates on 900Mhz or 1.2Ghz then you cannot use the plans as-is. However, you can modify them to work using the information found here: GP Patch FAQ.

Goof Proofing the Patch

I spent a bit of time trying to devise a way to minimize coax related obstacles. My biggest concern was with feedline length efficiency issues due to impedance mismatches and RF losses. I was also concerned that most folks do not have the experience to correctly install SMA connectors onto the coax (which requires expensive specialty tools). In the end, I decided that the only way to keep costs down, and to ensure absolute success, I had to eliminate the coax feedline.

The result is an antenna that has a integral SMA connector that screws directly onto the popular video receivers. There are no SMA connectors to crimp, no SWR problems, and no coax losses to deal with. Frankly, this method offers an ideal low-loss antenna feedpoint. It's inexpensive too. Did I mention it was goof proof?

Bigger and Better

Nearly all Patch antennas are simple circuit board designs, mainly because they are cheap to mass produce. They consist of a double sided circuit board, usually .06" thick, that has the reflector etched on one side and the driven element on the other. A coax is used as the feedline and the coax's connection point determines the feedpoint impedance.

However, printed circuit board (pcb) Patches are not as efficient as other construction techniques. The pcb has an exaggerated dielectric value that impacts the antenna design. Both aperture size and RF medium losses are typical issues. The thin dielectric, often barely just .01 wavelength in size, negatively reduces the overall *bandwidth* due to the close proximity of the driven element and reflector.

Even if zero loss Teflon circuit board substrate is used, there are still gain reductions that harm performance. That is because the circuit board material reduces the element size (due to its impact to antenna resonance) and it increases the beamwidth. Hence, there is usually *at least* a -3dB reduction in gain when pcb designs are employed.

A much more efficient Patch can be made if you use air (or vacuum) as the dielectric. With a dielectric constant of one (unity), it allows for a full size Patch element and presents a low loss interface between it and the reflector. Without the constraints of a circuit board, it is quite easy to use optimal reflector spacing (.04 wavelength is used here).

The antenna element is much larger on an air dielectric Patch. If you hold it up to a circuit board based antenna you will see that it is about 50% larger. Larger antennas, that are driven at resonance, have higher efficiency than those that are smaller. The photo on the right shows two 2.4GHz Patch antennas (the size difference is obvious).

Antenna modeling suggest that an air dielectric design can achieve gains in excess of 8dBi. This is a +6dB improvement over a traditional dipole and at least a +3dB advantage over most commercial Patch antennas. In a practical sense, every 3dB improvement in antenna performance will offer the same advantages as to doubling your transmitter's power. Now do I have your attention?



Tool Time

Very few tools and supplies are needed to build the Patch. You will need a 40 watt soldering iron, pair of tin snips or heavy shears, rubber cement or glue stick, epoxy adhesive or CA (crazy glue), a flat file, and a couple of drill bits (drill sizes shown on the downloadable plans).

Expected construction time is about a half hour. With practice, you can build one in ten minutes.



Three's a Crowd

There are only three materials needed to construct the antenna:

1. 5" x 7" piece of 24 to 30 gauge sheet metal (tin, brass, or galvanized).
2. 2 inch long piece of 0.20" square balsa, pine, or hardwood.
3. PCB mount SMA connector, Amphenol RFX #901-9895-RFX. Available at Mouser (p/n 523-901-9895-RFX) and Digi-Key (ARFX1229).



I purchased the sheetmetal at the hardware store (Lowe's). It was found in the roofing area and is sold in a plastic bag as "Galvanized Step Flashing." A package of ten 5"x7" pieces cost only $1.50, so that breaks down to fifteen cents an antenna. As a side bonus, any leftovers can be used to fix your leaky roof. I guess patching roofs and making Patch antennas is all the same thing to the sheet metal.

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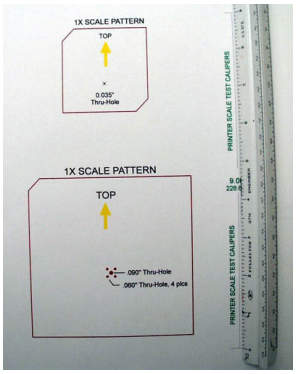
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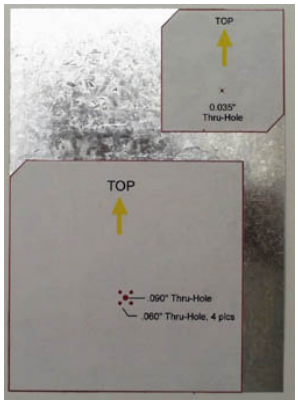
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Now cut out the two full scale paper patterns. The red border should be fully intact (cut on the **outside** edge).

Apply the rubber cement (or paper glue stick) to the back of the patterns and then place them on your sheet metal. If you align them as shown in the photo then only two sides of each pattern will need to be cut.

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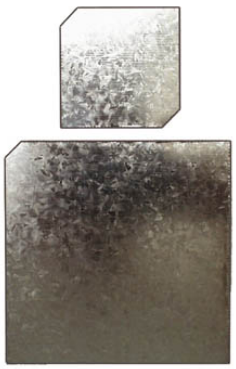
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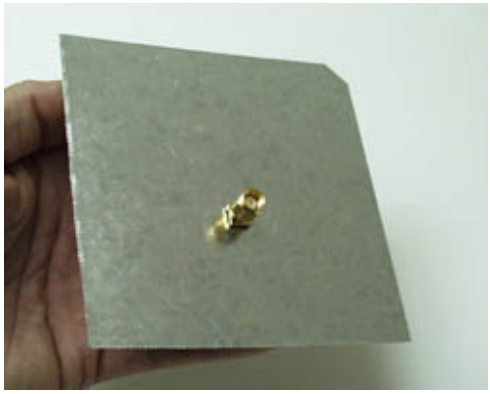
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The SMA connector is installed on the **backside** of the large reflector plate. It should drop into your drilled holes and sit perfectly flush on the surface.

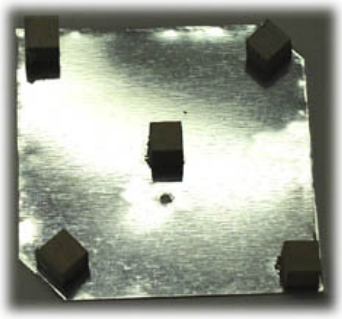
Solder the four ground legs on the front side. I found that clean galvanized steel or tin material flowed very well using a basic 40 watt iron and decent electronic solder.

After soldering, trim the SMA's four legs flush on the front side. Do NOT trim the center post.

The SMA's center post is a bit short and needs to be longer in order to reach the driven element when it is added in a future step. Merely solder a short piece of 24-26 AWG solid wire (a .5" long resistor lead works well) onto the end of the center post. When you are done it should extend the post by about a quarter inch.

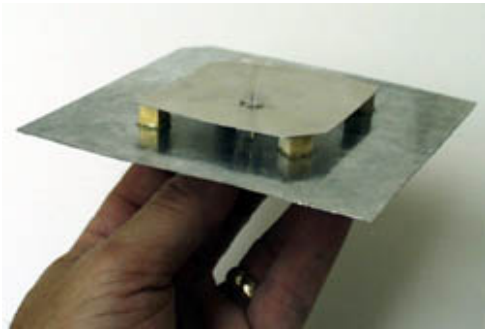
Now clean off ALL the solder flux. Do not omit this step.

Now it's time to cut out the wood spacer blocks. You will need five pieces that are .20" square by about .25" long (5mm x 5mm x 6mm). The critical thing is to maintain the 0.20" dimension as close as you can since it will set the element spacing when the two metal parts are combined.



Using a small amount of epoxy or CA adhesive, glue the wood blocks to the center and four corners of the small element's **bottom side**. Place them on the sheet metal so that the .20" dimension (not the .25" side) sets their height . Allow the glue to dry. If you don't want to wait long then use fast cure 5-minute epoxy or CA.

Now its time for a dry fit of the two panels. Align the hole in the element over the SMA's extended post on the reflector. Slide the two parts together so that the SMA's center post passes through the small element panel.



The reflector's beveled corner (orientation mark) should be at the upper left. The element's two beveled corners should be at the upper left and lower right. The two panels should appear to be centered over each other with the SMA offset towards the bottom.

If you like the fit then remove the element and apply a small dab of epoxy to the top of the wood blocks. Put the two parts together again and ensure that they are perfectly centered.

While the glue is drying, solder the SMA's center post to the element. Be very careful or the little wire stub you added will come free from the SMA if its solder reflows. I suggest you solder it while the adhesive is still wet so that you can pull the panels apart if you run into trouble. Cut off the excess wire stub when you are done and allow the adhesive to cure.



The antenna is now complete! Just screw it onto the SMA of your video receiver and aim it towards your R/C model. The arrow shown on the template is the orientation for use with transmitters with vertical polarization (e.g., vertical Tx whips). If yours is horizontally polarized then rotate the patch 90^{o}.

The photo on the left shows the Patch screwed onto my video receiver. Other than the SMA coupling, nothing is holding the Patch. I will probably add a bracket to support it in order to prevent SMA connector damage.

By the way, the PVC stand works great -- construction details to it are available on the RC-CAM Field Equipment page.

*GP Patch FAQ:

It is important to note that the success of any antenna project requires that you follow the recipe exactly as shown. Improvising is not a good idea since everything matters at microwave frequencies. Here are some common questions about making changes to the design:

Q: *I have two video systems that operate at 900Mhz and 1.2Ghz. Can I use the GP Patch?*
A: You can use it at other UHF and microwave frequencies by re-scaling the design. This is a process where ALL the dimensions are increased to suit the required operating frequency. It is important to know the exact frequency of your system, so a frequency counter is often needed.

To scale the antenna for your required frequency please use this formula:
Scale Factor = 2400Mhz / Required Mhz

Example: Cheap imported "1.2Ghz" wireless video system (usually operate at 1.16Ghz):
2400Mhz / 1160Mhz = 2.069

Q: *I computed the scaling factor. My system runs exactly at 1.20Ghz so the scale is 2.00. Just what do I do with that number?*
A: You multiply ALL the dimensions {as shown on the plans} with the scaling number. Accuracy counts. The antenna will become larger, so you might want to use heavy gauge sheet metal so that the bigger size survives rough handling.

Q: *Ok, I printed the plans. Then I carefully increased the sheet metal size using the scaling number I computed. Do I also increase the size of the wood spacer blocks?*
A: Yes, you must increase the size of EVERYTHING.

Q: *I built the stock antenna and I decided to use coax to connect the antenna to the receiver. It seems to work. Is that OK?*
A: If you are happy then I am happy. However, you just robbed your video system's performance. Why? Well, typical coax is VERY lossy at microwave frequencies and so your range has been substantially compromised.

If it were me, I would get rid of the coax and mount the receiver directly on the antenna. But, if you like the performance with the coax then leave it in place (just keep in mind that better range is possible with it removed).

Q: *Do I really need to use the SMA connector shown on the plans? Can I use a common TV F-connector? Or, can I solder directly to the antenna with coax or other wire?*

A: For 2.4Ghz use, I highly recommend you use a microwave rated connector like the plans call out. Everything else invites RF loss and will reduce antenna performance. Most 2.4Ghz systems will mate with the SMA connector as shown. Cheap imported 1.2Ghz systems often use a TV F-connector, so your GP Patch should use its mate instead. Beyond this, if you must improvise then seek help from someone that has experience with antennas.

Q: *What is the impedance of the GP Patch?*
A: It is about 50 ohms. You can use it with a 50 to 75 ohm receiver.

Q: *Can I connect two GP Patch antennas together to obtain more gain?*
A: Short answer: No. Long answer: Patch arrays are more complicated than that. Without careful impedance matching, then results will be dismal.

Q: *I heard that patch antennas are directional. I do not want to have to aim it at my R/C airplane as I fly around. What do you suggest?*
A: You should find that constantly aiming the GP Patch is NOT necessary. Just point it in the direction you fly in. There is no need to aim it like a flashlight

Q: *What do the 45 degree cut corners on the sheetmetal do?*
A: The original goal was to try to entice the patch to be circularly polarized. Along with the cut "dog ears," some early design attempts had 90 degree phase coherent feedpoints. They were too complicated, easy to mess up during assembly, and the results seemed to indicate that significant circular polarization operation was not achieved. However, the final design's performance validations were done with the dog eared cut corners and I did not want to go back and re-optimize the design with them off. So, they remain in place. Folks that use the original dimensions, or scale from them, should also cut the dog-eared corners as shown.

Beware of the Fine Print:

All information is provided as-is. I do not offer any warranty on its suitability. That means that if you build and use this device, you will do so at your own risk. If you find documentation problems then please report them to me.

FeedBack:

If you have technical questions or comments about this project then please post it on the rc-cam project forum.

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- RC-CAM4
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- Movie Catalog
- Questions?
- FPV Videos
- Forums



GP PATCH ANTENNA (Goof-Proof Patch)

Building a high performance Patch Antenna may seem like a daunting task. But assembling your own is actually quite easy and these instructions make it nearly goof-proof. This Patch will outperform commercially made versions that use lower efficiency circuit board construction.

Introduction

It is no secrete that the most important component in your wireless video system is the antenna. While most folks are investing in more powerful transmitters, you can obtain additional range merely by concentrating your efforts on the antennas that are used. For sure, in our R/C wireless camera application, where the transmitter is a moving target, antenna choices require some care during the selection process.

Antennas come in many flavors, but the ones that are supplied with most imported "sardine can" video systems are dipoles and vertical whips. These are considered to be omni directional antennas and are fine for basic consumer applications. And although there are better choices, they have been used with good success on the transmitter end of an airborne R/C video system. However, these omni antennas are the system's achille's heel when they are used on the ground based receiver.

I have found that a higher gain antenna with a reduced *beamwidth* is best for use on the receiver's end. The extra gain extends your range and limiting the beamwidth helps reduce multi-path interference and minimizes the capture of extraneous signal sources (the 2.4GHz band is full of consumer RF devices).

And in order for mortals like me to build it, home brew antenna projects must be very simple and nearly goof proof. Better still, step-by-step instructions would be nice to have. Up until now, that laundry list of requirements seemed like an very tall order. But not any longer, as you will soon see.

A Patch is Hatched

Since I experienced good results with commercially purchased Patch antennas, I decided to concentrate my efforts on documenting a 2.4GHz (13cm) ham band Patch that others could build for themselves. My goal was to present a set of plans that nearly any opposing thumb equipped mammal could understand (some lower primates excluded) and present the information in such a way that success would be nearly guaranteed.

The Patch antenna shown here is a good performer when used on a 2.4GHz video receiver. It has more gain (estimated at nearly 3dB higher) than my battle worn X10 Patch. Depending on the exact frequency used, gain is estimated to be from +5dBi to +8dBi. The antenna is linear polarized. Beamwidth is broad enough so that antenna aiming is minimized.

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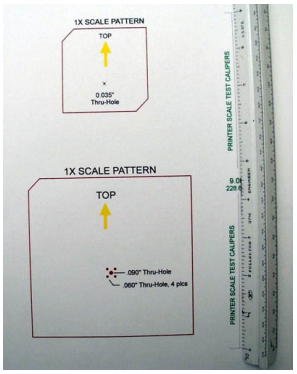
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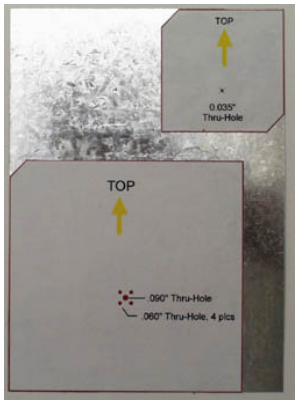
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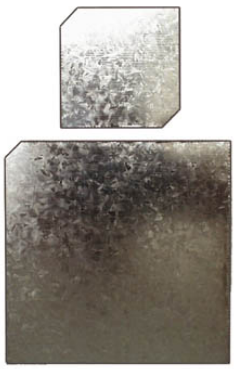
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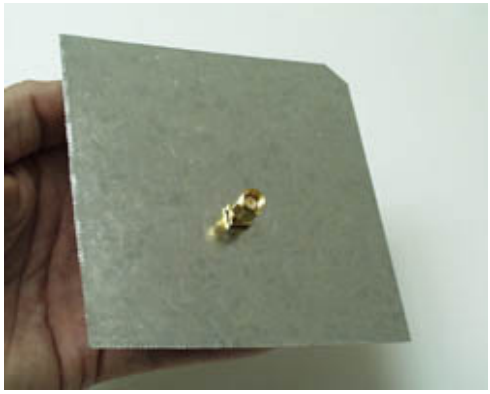
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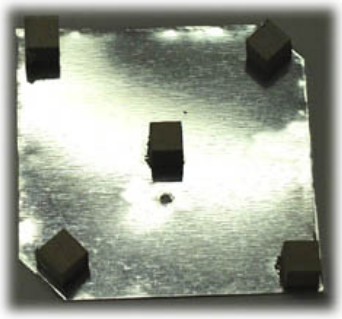
Solder the four ground legs on the front side. I found that clean galvanized steel or tin material flowed very well using a basic 40 watt iron and decent electronic solder.

After soldering, trim the SMA's four legs flush on the front side. Do NOT trim the center post.

The SMA's center post is a bit short and needs to be longer in order to reach the driven element when it is added in a future step. Merely solder a short piece of 24-26 AWG solid wire (a .5" long resistor lead works well) onto the end of the center post. When you are done it should extend the post by about a quarter inch.

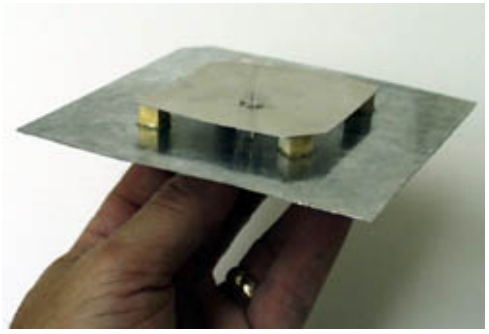
Now clean off ALL the solder flux. Do not omit this step.

Now it's time to cut out the wood spacer blocks. You will need five pieces that are .20" square by about .25" long (5mm x 5mm x 6mm). The critical thing is to maintain the 0.20" dimension as close as you can since it will set the element spacing when the two metal parts are combined.



Using a small amount of epoxy or CA adhesive, glue the wood blocks to the center and four corners of the small element's **bottom side**. Place them on the sheet metal so that the .20" dimension (not the .25" side) sets their height . Allow the glue to dry. If you don't want to wait long then use fast cure 5-minute epoxy or CA.

Now its time for a dry fit of the two panels. Align the hole in the element over the SMA's extended post on the reflector. Slide the two parts together so that the SMA's center post passes through the small element panel.



The reflector's beveled corner (orientation mark) should be at the upper left. The element's two beveled corners should be at the upper left and lower right. The two panels should appear to be centered over each other with the SMA offset towards the bottom.

If you like the fit then remove the element and apply a small dab of epoxy to the top of the wood blocks. Put the two parts together again and ensure that they are perfectly centered.

While the glue is drying, solder the SMA's center post to the element. Be very careful or the little wire stub you added will come free from the SMA if its solder reflows. I suggest you solder it while the adhesive is still wet so that you can pull the panels apart if you run into trouble. Cut off the excess wire stub when you are done and allow the adhesive to cure.



The antenna is now complete! Just screw it onto the SMA of your video receiver and aim it towards your R/C model. The arrow shown on the template is the orientation for use with transmitters with vertical polarization (e.g., vertical Tx whips). If yours is horizontally polarized then rotate the patch 90^{o}.

The photo on the left shows the Patch screwed onto my video receiver. Other than the SMA coupling, nothing is holding the Patch. I will probably add a bracket to support it in order to prevent SMA connector damage.

By the way, the PVC stand works great -- construction details to it are available on the RC-CAM Field Equipment page.

*GP Patch FAQ:

It is important to note that the success of any antenna project requires that you follow the recipe exactly as shown. Improvising is not a good idea since everything matters at microwave frequencies. Here are some common questions about making changes to the design:

Q: *I have two video systems that operate at 900Mhz and 1.2Ghz. Can I use the GP Patch?*
A: You can use it at other UHF and microwave frequencies by re-scaling the design. This is a process where ALL the dimensions are increased to suit the required operating frequency. It is important to know the exact frequency of your system, so a frequency counter is often needed.

To scale the antenna for your required frequency please use this formula:
Scale Factor = 2400Mhz / Required Mhz

Example: Cheap imported "1.2Ghz" wireless video system (usually operate at 1.16Ghz):
2400Mhz / 1160Mhz = 2.069

Q: *I computed the scaling factor. My system runs exactly at 1.20Ghz so the scale is 2.00. Just what do I do with that number?*
A: You multiply ALL the dimensions {as shown on the plans} with the scaling number. Accuracy counts. The antenna will become larger, so you might want to use heavy gauge sheet metal so that the bigger size survives rough handling.

Q: *Ok, I printed the plans. Then I carefully increased the sheet metal size using the scaling number I computed. Do I also increase the size of the wood spacer blocks?*
A: Yes, you must increase the size of EVERYTHING.

Q: *I built the stock antenna and I decided to use coax to connect the antenna to the receiver. It seems to work. Is that OK?*
A: If you are happy then I am happy. However, you just robbed your video system's performance. Why? Well, typical coax is VERY lossy at microwave frequencies and so your range has been substantially compromised.

If it were me, I would get rid of the coax and mount the receiver directly on the antenna. But, if you like the performance with the coax then leave it in place (just keep in mind that better range is possible with it removed).

Q: *Do I really need to use the SMA connector shown on the plans? Can I use a common TV F-connector? Or, can I solder directly to the antenna with coax or other wire?*

A: For 2.4Ghz use, I highly recommend you use a microwave rated connector like the plans call out. Everything else invites RF loss and will reduce antenna performance. Most 2.4Ghz systems will mate with the SMA connector as shown. Cheap imported 1.2Ghz systems often use a TV F-connector, so your GP Patch should use its mate instead. Beyond this, if you must improvise then seek help from someone that has experience with antennas.

Q: *What is the impedance of the GP Patch?*
A: It is about 50 ohms. You can use it with a 50 to 75 ohm receiver.

Q: *Can I connect two GP Patch antennas together to obtain more gain?*
A: Short answer: No. Long answer: Patch arrays are more complicated than that. Without careful impedance matching, then results will be dismal.

Q: *I heard that patch antennas are directional. I do not want to have to aim it at my R/C airplane as I fly around. What do you suggest?*
A: You should find that constantly aiming the GP Patch is NOT necessary. Just point it in the direction you fly in. There is no need to aim it like a flashlight

Q: *What do the 45 degree cut corners on the sheetmetal do?*
A: The original goal was to try to entice the patch to be circularly polarized. Along with the cut "dog ears," some early design attempts had 90 degree phase coherent feedpoints. They were too complicated, easy to mess up during assembly, and the results seemed to indicate that significant circular polarization operation was not achieved. However, the final design's performance validations were done with the dog eared cut corners and I did not want to go back and re-optimize the design with them off. So, they remain in place. Folks that use the original dimensions, or scale from them, should also cut the dog-eared corners as shown.

Beware of the Fine Print:

All information is provided as-is. I do not offer any warranty on its suitability. That means that if you build and use this device, you will do so at your own risk. If you find documentation problems then please report them to me.

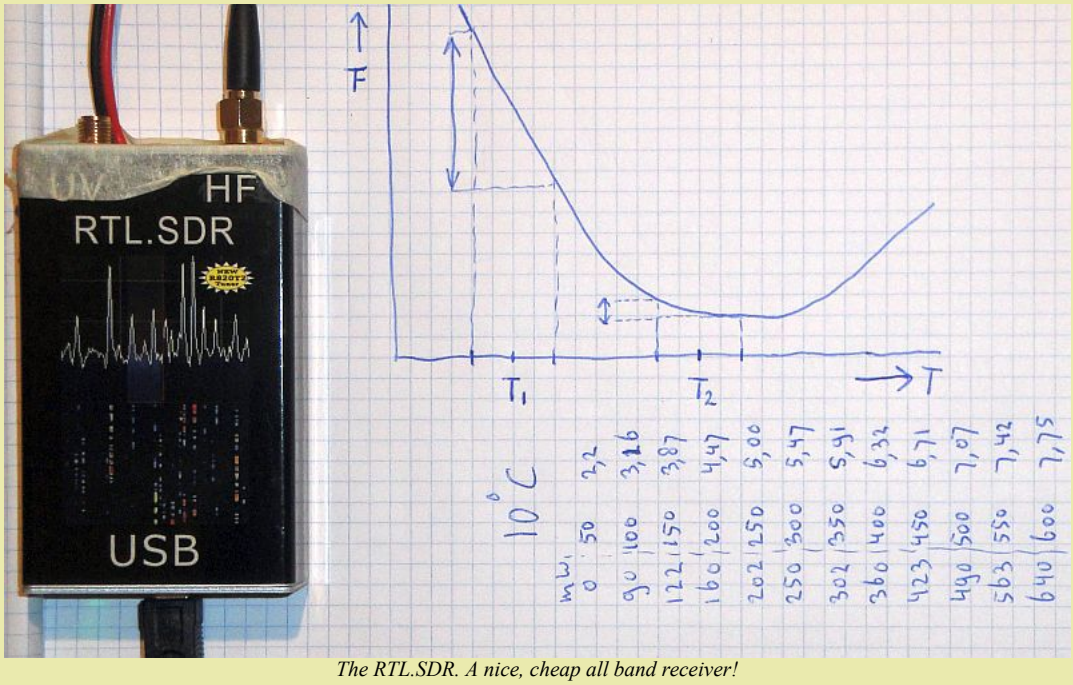
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RTL.SDR FREQUENCY STABILIZER

2017

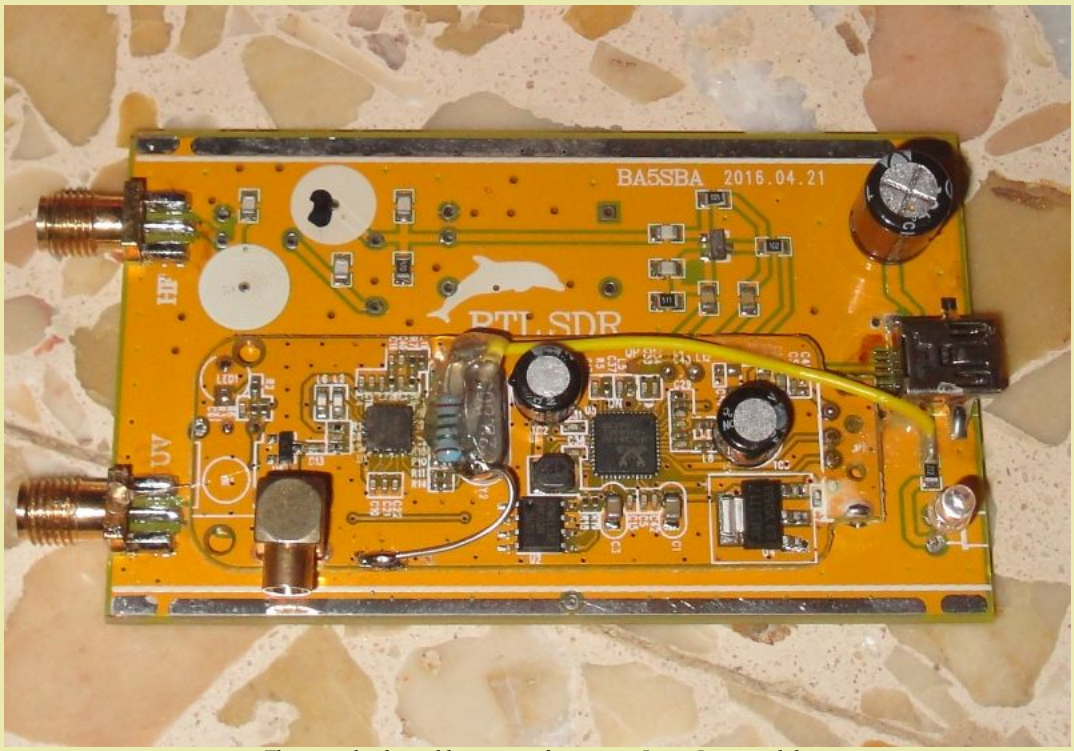


The RTL.SDR. A nice, cheap all band receiver!

Temperature stabilization

This might be the most simple circuit I ever made, only one resistor!

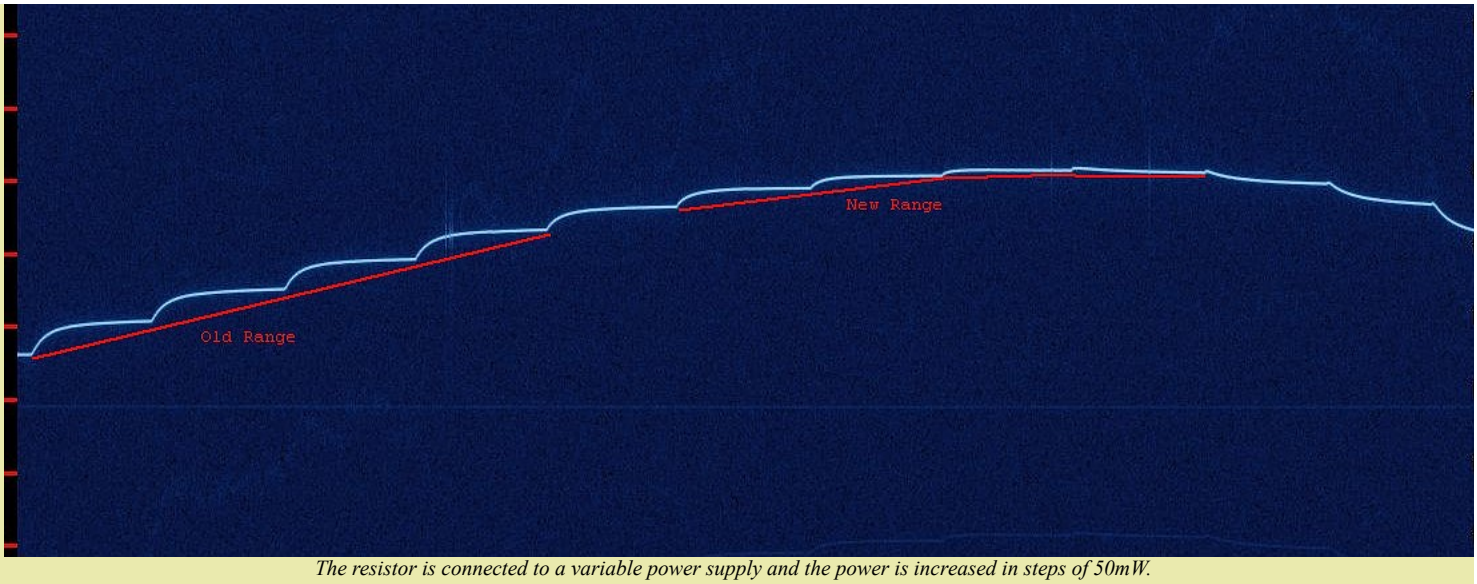
I got such an RTL.SDR and it is really a nice, cheap all band receiver! But when I wanted to use it as a grabber, it needed some temperature stabilization, as the drift was just a little too much. With only one resistor, it was possible to reduce the drift from 18Hz to 5Hz in the temperature range from 10C to 30C and even from 12Hz to 2Hz in the temperature range from 15C to 30C.



The crystal is heated by means of a resistor. Later, I mounted the resistor on top of the crystal and turned the receiver upside down.

How it works

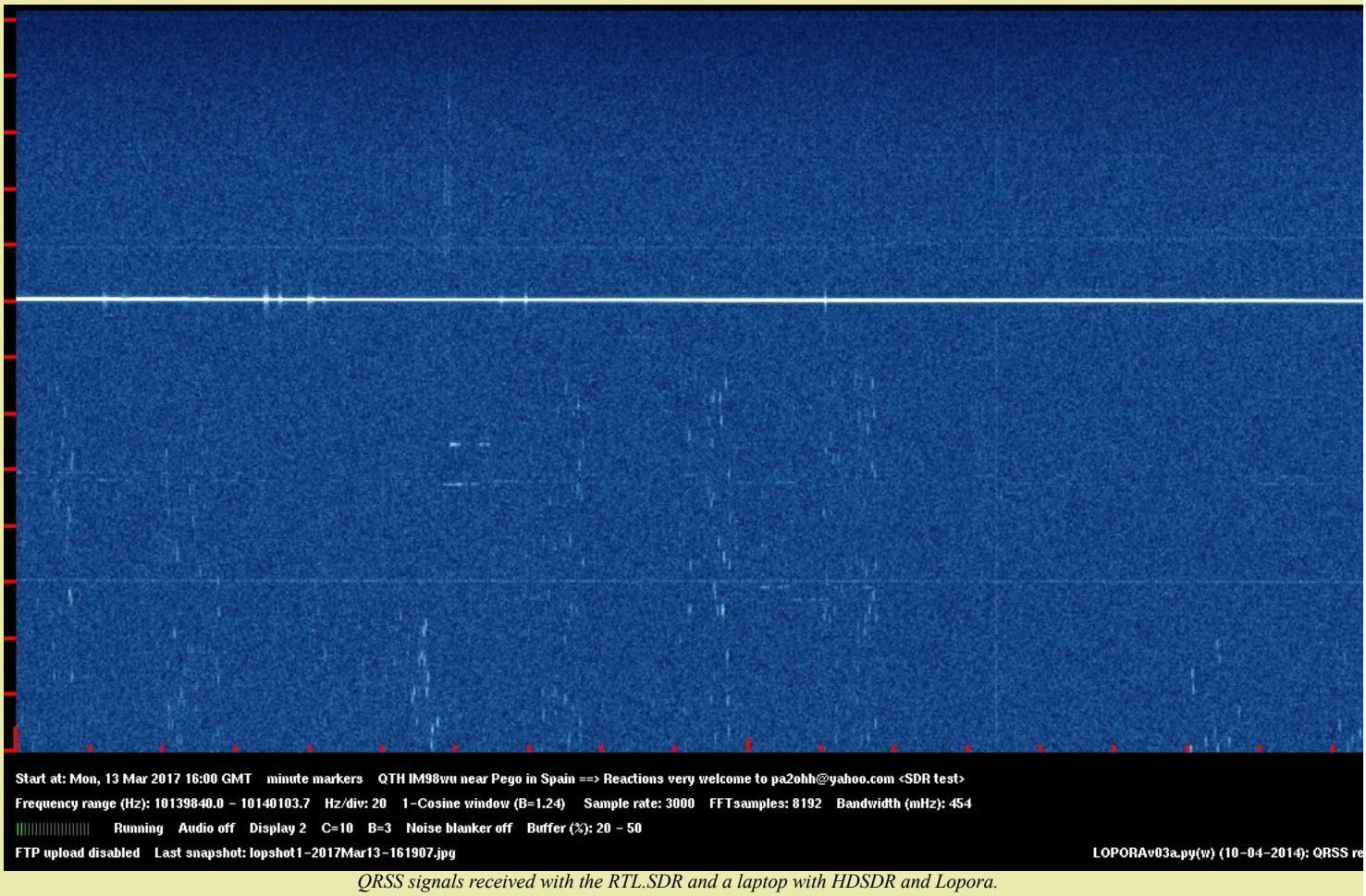
The crystal is heated by means of a resistor mounted on the crystal. It is heated to the turnover point. Below that point, the frequency of the crystal goes down, above that point the frequency goes up. But around that point the crystal frequency is much less affected by the temperature than at room temperature! So the trick is to heat the crystal that its temperature is at the turnover point during the average room temperature of the RTL.SDR



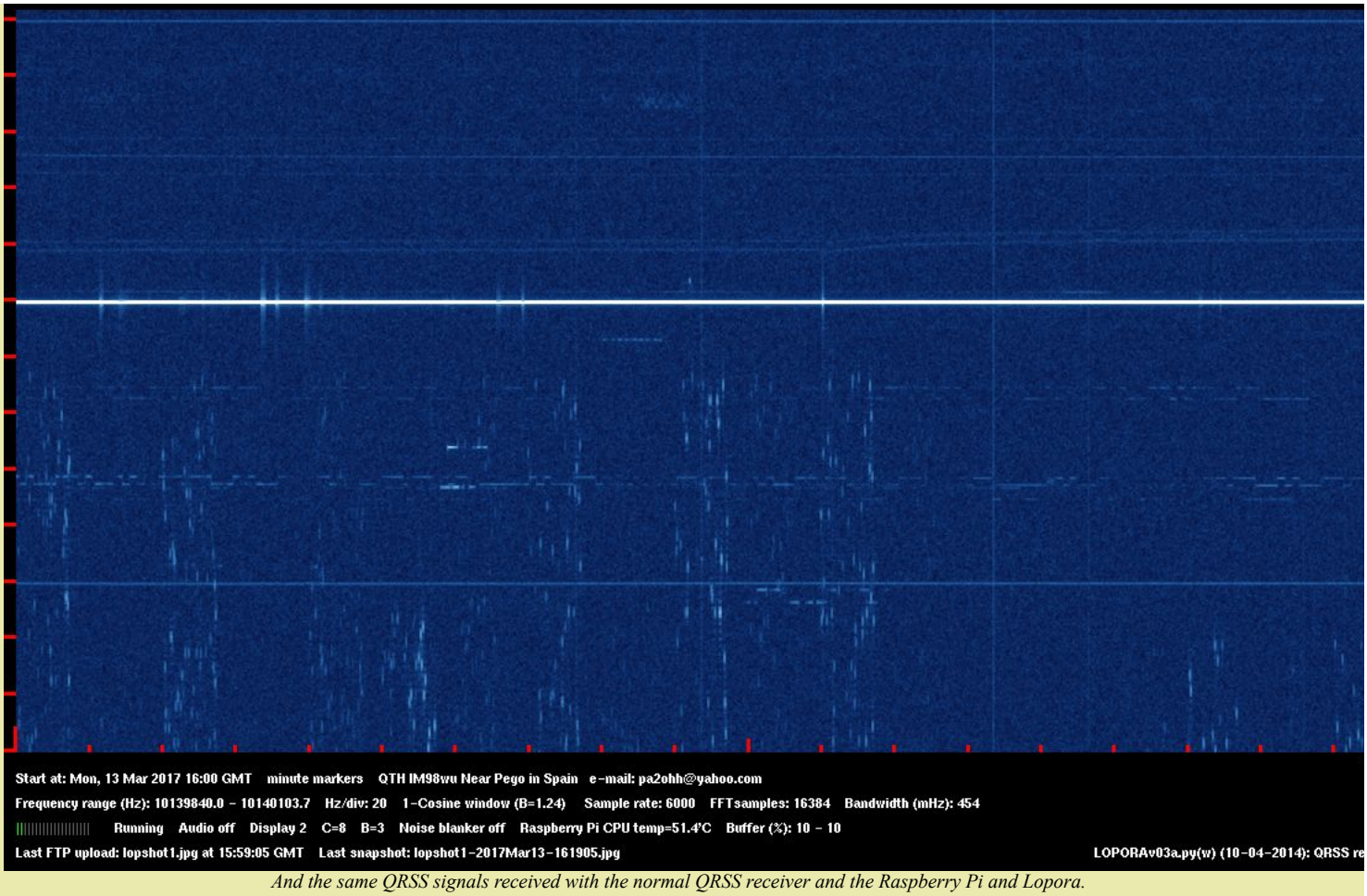
The resistor is connected to a variable power supply and the power is increased in steps of 50mW.
One step is approximately 5C. It starts at the left at only 10C that evening.

How to determine the value of the resistor
I connected a reference frequency of the GPS standard to the RTL.SDR dongle and displayed it on the grabber made with Lopora. When the frequency of the crystal goes up, the graph goes down, as it displays the received tone, that goes just in the opposite direction of the crystal frequency.
The resistor is connected to a variable power supply and the power is increased in steps of 50mW. When I did this test, it was only 10C in my radio lab, so the lowest room temperature instead of the average room temperature. You can see that it reaches its turnover point but that not far above that point, the temperature dependency quickly becomes worse. So avoid to go over that point. When the crystal frequency goes down, the graph goes up, as th
I needed 250mW and that means a resistor of 100 ohm connected to the 5 volt supply of the RTL.SDR

Results
The drift was reduced from 18Hz to 5Hz in the temperature range from 10C to 30C and even from 12Hz to 2Hz in the temperature range from 15C to 30C. So very acceptable. It was possible to receive many QRSS stations, but the sensitivity of my normal QRSS receiver is approximately 6dB better. Of course the RTL.SDR will perform better with a narrow band filter, but then it is perhaps better and simpler to use an ordinary receiver without SDR software. But for you first experiences with QRSS, it is worth to buy such an RTL.SDR. It can do so much more than only QRSS!



QRSS signals received with the RTL.SDR and a laptop with HDSDR and Lopora.



And the same QRSS signals received with the normal QRSS receiver and the Raspberry Pi and Lopora.

BACK TO INDEX PA2OHH

FREQUENCY COUNTER

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5

FREQUENCY COUNTER

Designed by Mani T. K VU2 ITI

Introduction:

A frequency meter is a measuring equipment to measure the frequency or number of cycles per unit time of an input signal to it. Frequency meter can be of analogue type and digital type. In analogue type, the frequency is indicated on a calibrated a needle type meter. Where as, a digital frequency counter gives the frequency reading on a digital display. Digital frequency counter are easy to read and reading error is minimum. There are so many other advantages for a digital frequency counter. Now day analogue frequency meters are used to measure low frequencies only. Digital frequency counter is being used for wide range of application. Digital frequency counter extensively uses digital circuits and hence a fairly good knowledge of digital circuits and of digital integrated circuits is required to understand the operation of the frequency counter. However this article has been written in such a way to assemble the counter by a person who is not familiar with any electronic circuits and experiments.

Theory of operation.

As said earlier, the frequency counter has to count the number

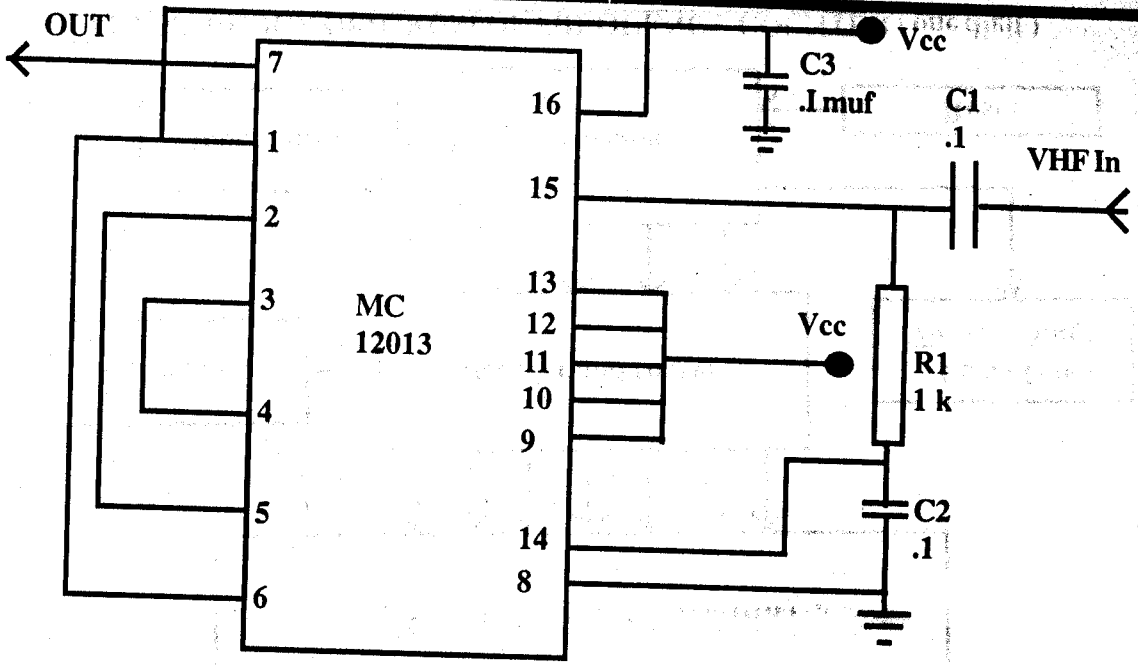


FIG. 5.1 CIRCUIT DIAGRAM OF VHF PRESCALAR

of cycles per second of an incoming signal. Hence we need a device to count. In digital circuits, counter ICs are available for counting. These ICs can count the input digital pulses. The count is given as coded output from the IC (in binary form or in BCD form.) The count value must be converted into decimal digit to be under stood by the human being. More number of ICs can be cascaded to increase the number of digits. The number of digits required for the counter to display the count value depends on the application and the accuracy needed. There is a variety of counter ICs available. In our design we use single 4 bit BCD high-speed CMOS counter chips. One chip is used for one digit and we use 7 similar ICs to get a seven digit counter. Also we use CMOS decoder IC to decode the BCD output of the counter to drive 7 segment displays. The block diagram of a counter is as shown

Since the counter can count only digital pulses, we need to convert the incoming signal wave to digital pulse or we should obtain one pulse for every input wave. Hence we need a special circuit to shape the input wave into a square wave of same frequency and amplitude confined to the TTL signal levels. A signal conditioning section is needed for this purpose.

The input Signal-conditioning section consists of the following stages

* Amplifier or attenuation stage
* TTL level converter stage

Besides the above essential stages, some times a few more

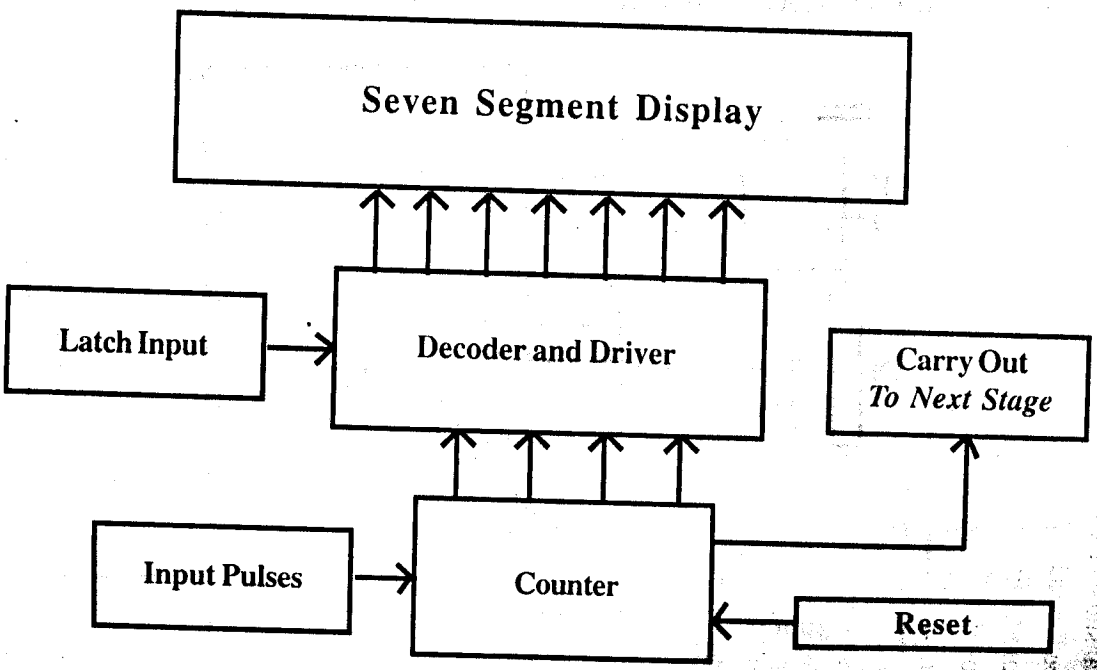


FIG. 5.2 BLOCK DIAGRUM OF FREQUENCY COUNTER (one digit)

additional stages such as input protection stages, filter stages, etc are can be found in some designs. The input whose frequency is to be measured is given to the input stage consisting of the above and the output of this stage is the square pulses. Now this square pulses are given to the counter to count the number of pulses for a fixed duration. If the duration is 1 seconds, then the counter displays a value that is equal to the number of cycles per second. Now if we want to measure a frequency of say 20 MHZ, the counter should display 20000000. This means that the counter should have 8 digits to display. Now the resolution of the counter (minimum change is frequency that can be displayed is 1 HZ. If do not require that much of resolution, we can reduce the number of digits. For example, if we are counting the input cycles for duration of 0.1 seconds, the display shows 2000000. Now if we put a decimal point after two digits from the left of the display, the frequencies can be read in Meg Hertz, in both cases, resolution for the later being 10 Hz. The time for which the counter is counting is called as gating time and if the gating time is say 1 millisecond, we get a display with a resolution of 1 kHz. A frequency counter must always count the input frequency and display the frequency. This means there should be an arrangement to count the input for a fixed time, display the reading. While displaying the reading, the counter should clear again to read the input again. Then only we get a continuous reading that displays the correct frequency at all times. A control circuit is needed to achieve this. The function of the control circuit to generate the following signals.

1. Clear the counter for a fresh reading
2. Provide a precision gating signal to allow the input pulses to

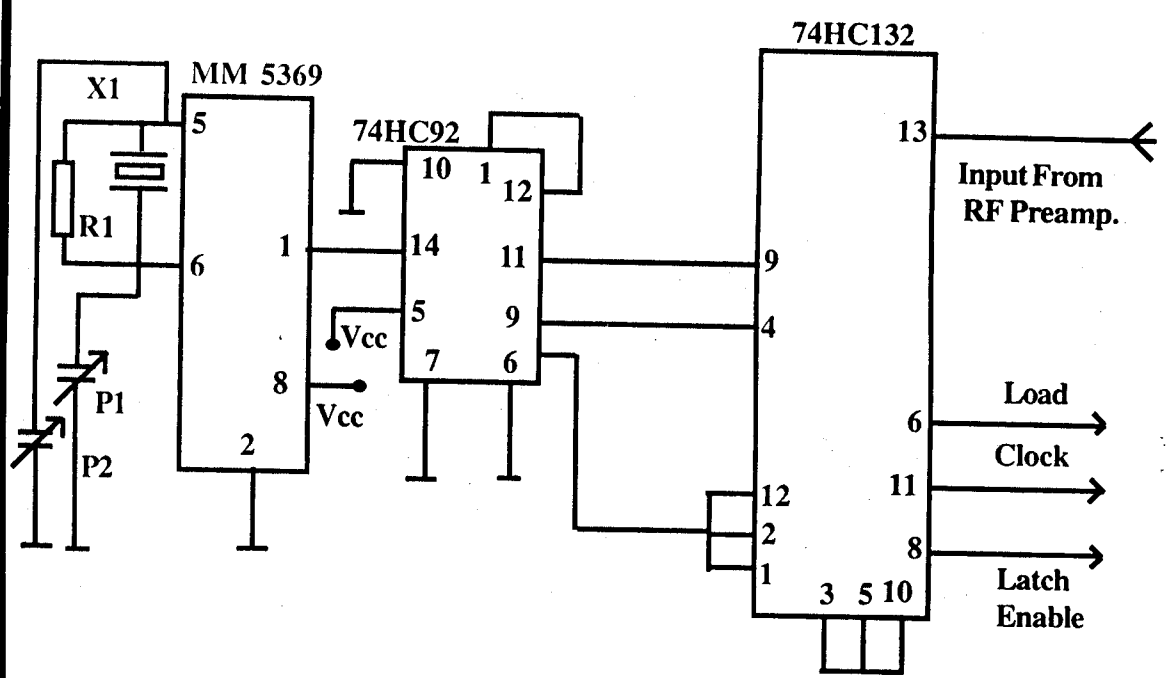


FIG. 5.3 DIAGRAM OF TIME BASE CIRCUIT

the counter to count

3. Latch the count value to decode and display.
4. Repeat the above steps continuously to get a continuous reading

The control circuit must operate with precision timing. This is achieved by deriving all timing signals from a crystal oscillator or time base circuit. The accuracy of the counter solely depends on the stability and accuracy of the time base circuit.

THE CIRCUIT

The counter circuit is designed using discrete digital ICs. The numbers of ICs are more in this design. However cost of the counter well lower than a single IC design. The circuit is capable of counting up, counting down and also capable of programming with an initial count value. This feature is often required if you want to know the frequency of a station tuned by using your super heterodyne receiver. We can display the station tuned in by measuring the local oscillator frequency. The actual frequency is + or - If frequency from the local Oscillator frequency. The IF frequency can be loaded by using the dip switches on the counter board. (BCD value).

The counter chip used is 74hct190. This IC consumes less power and counts up to say 50 MHZ. If you are not is a position to get HCT version you can replace the same with any family of 74 series. The decoder IC is CD4511. This is a CMOS IC consisting of a latch, decoder, and seven segment LED driver.

The control circuit is designed using the freely available

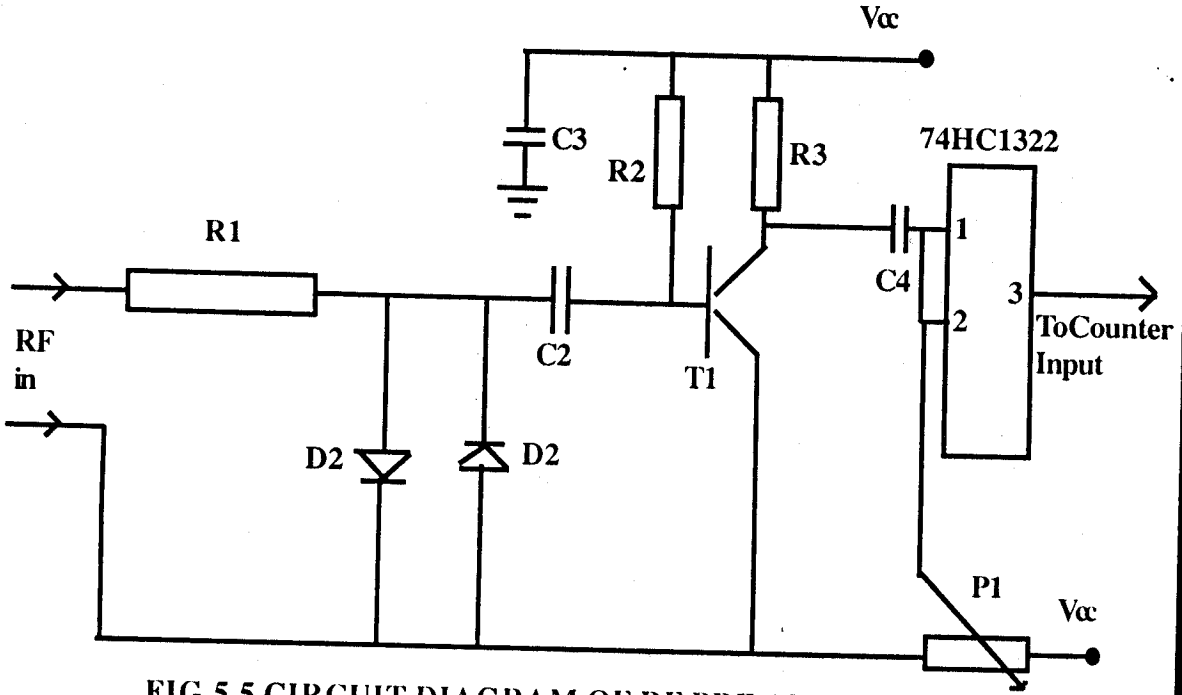
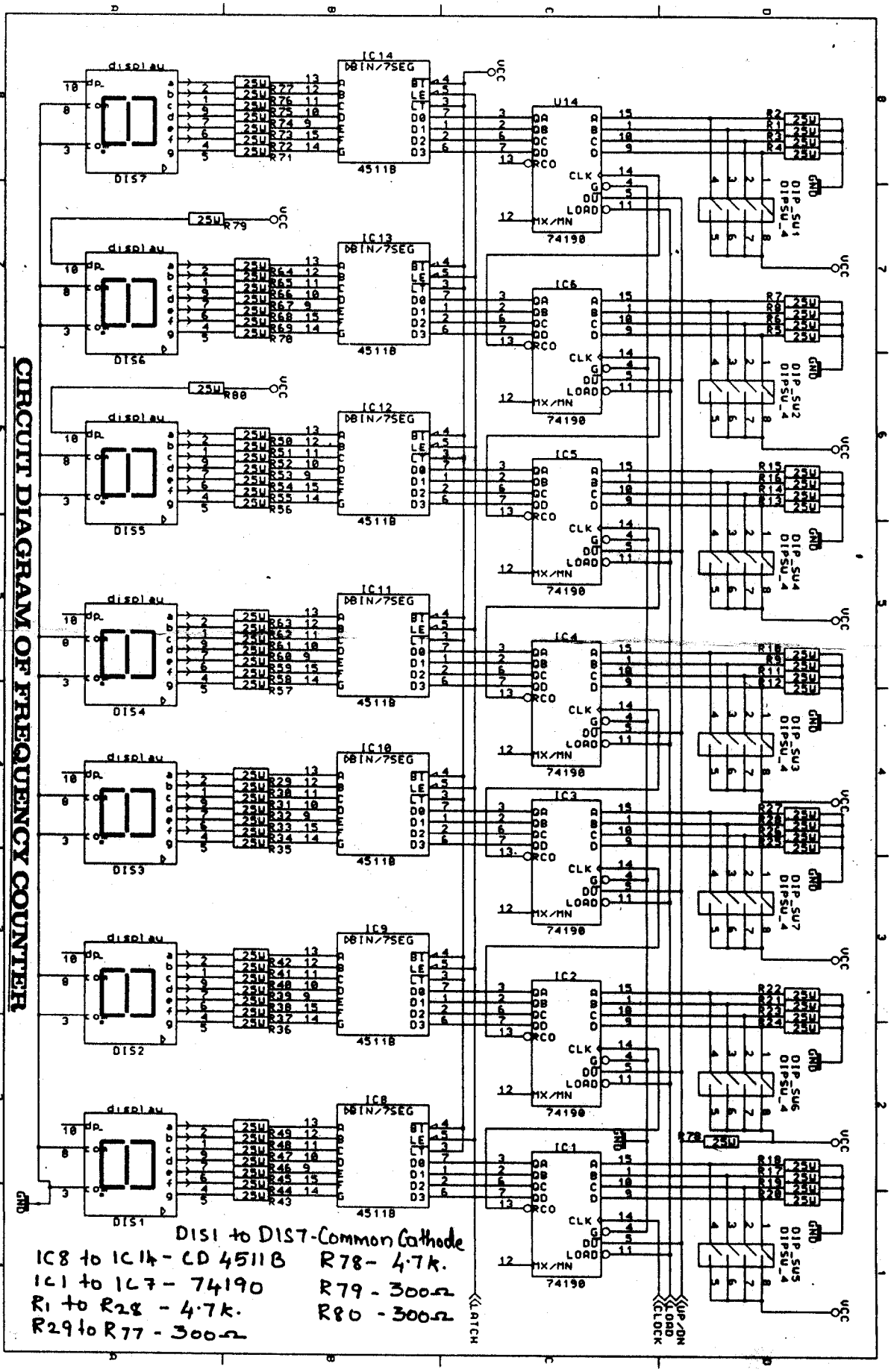


FIG.5.5 CIRCUIT DIAGRAM OF RF PRE AMPLIFIER


CIRCUIT DIAGRAM OF FREQUENCY COUNTER
DIS1 to DIS7-Common Cathode
IC8 to IC14 - CD 4511B
IC1 to IC7 - 74190
R1 to R28 - 4·7k.
R29 to R77 - 300Ω
R78 - 4·7k.
R79 - 300Ω
R80 - 300Ω
LATCH
UP/DN
LOAD
CLOCK
GND
VCC

time base chip MM 5369 and other two TTL chips. The 5369 consists of a crystal oscillator and a divider. If we connect a crystal of 3.579 MHZ we get 60 Hz frequency as output. This frequency is divided again by divided by 12 counter chip IC 7492. Together with 7492 and the schmitt trigger NAND gates the necessary control signals are derived . The gating time is 100 milli seconds and hence the frequency shown is 1/10 th of the actual frequency in Hz .

The input section consists of a single transistor RF pre amplifier. Diode limiters are provided at the input to protect the transistor from high RF voltages if applied. The sensitivity of the counter is around 100 milli volts. A potentiometer is included in the circuit to adjust for proper operation of the counter. If you need more sensitivity, you can add a preamplifier to the front end. If you need to measure audio frequencies using this counter, then the preamplifier must be changed.

The counter is capable of counting frequencies of all HF signals, but if you need to measure VHF frequencies, you need a pre-scalar. Which divides the input by a factor say 10 so that the output is now 1/10 of the input. This frequency is now in the HF range and can be easily read by the counter. Actual frequency is now 10 times the displayed frequency. A suitable pre scalar for VHF counting is also given in the circuit. The Pre-scalar needs an input voltage of 500 mV to function. Hence you may require a VHF preamplifier to measure signals below 500mV amplitude.

CONSTRUCTION

Proper care is to be taken in selecting the components, han dling and soldering the components. It is always better to assemble the circuit on a printed circuit board. The author can provide the PCBs, provided the over all requirements are about 25. IC bases are highly recommended for the homebrewed who's not very familiar with digital circuits while IC bases are not recommended for an experienced builder as IC bases may cause loose connections and decrease the high frequency performance.

Procure all components from a reliable source so as to avoid confusion in a later stage.

Assemble the IC bases and connectors first, followed by all resistors and capacitors. Control circuit can be tested easily with a logic probe. The preamplifier also can be tested with the help of RF probe. Normally there wont be any problem if every thing is assembled in a proper way.

The counter needs a 5V highly stabilised power supply capable of delivering about 1 amperes. 3 terminal regulator IC 7805 is sufficient for this purpose. If power supply is not proper there can have malfunctioning for the counter.

Power supply to all IC's are to be decoupled with .01 uf capacitor connected across the Vcc and Gnd pin with shorter leads . There can have several malfunctions if power is not properly decoupled .

COMPONENTS DETAILS FOR TIME BASE CIRCUIT .

No.	Item ID.	Description .
1.	R1	1 M
2.	X1	3.579 MHz
3.	P2	22 PF TRIMMER
4.	P1	33 PF
5.	IC'S	MM 5369
		74HC92
		74HC132

COMPONENT DETAILS FOR RF PRE.AMP .

1.	R1	1 K
2.	R2	1M
3.	R3	2.2 K
4.	P1	10 K
5.	DI	IN 4148
6.	D6	IN 4148
7.	C2	.1 UF
8.	C3	.1 UF
9.	C4	.1 UF
10.	T1	2N 918
11.	IC	74HC132

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Microstrip dipole antenna for WLAN application

Conference Paper · December 2005

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MICROSTRIP DIPOLE ANTENNA FOR WLAN APPLICATION

M.H. Jamaluddin, M.K. A. Rahim M. Z. A. Abd. Aziz, A. Asrokin

Wireless Communication Center (WCC),
Faculty of Electrical Engineering,
Universiti Teknologi Malaysia,
Email: haizal@fke.utm.my, mkamal@fke.utm.my , matjoin@yahoo.com, awi82@yahoo.com

***Abstract*— This paper describes numerical simulation, fabrication and experimental measurement of microstrip dipole antenna at 2.4 GHz for WLAN application. In this antenna design, Agilent's ADS software using momentum simulation is employed to analyze the entire structure. The properties of antenna such as bandwidth, radiation pattern and half power beamwidth have been investigated and compared between simulation and measurements. The cross-polar isolation of the microstrip dipole antenna is in the range of 3 to 17.32 dB. The typical half power beamwidth (HPBW) of the microstrip dipole is 60º for E plane and 75º for H plane. Performance comparison between dipole and monopole antenna is also made in term of bandwidth and Input return loss.**

Keywords- *Microstrip antenna;microstrip dipole; WLAN*

I.INTRODUCTION

Wireless communication has developed widely and rapidly in modern world. Wireless local area networks (WLAN) are emerging technologies that will have dramatically effect in the near future. WLAN takes advantage of a license free frequency bands, Industrial, Scientific and Medical (ISM) which specify the operating frequencies as 2.4 and 5.2GHz [1-2].

Microstrip antennas are frequently used in today's wireless communication systems because of their low profile, light weight and low production cost which widely have been researched and developed in the recent twenty years [3-6]. Nevertheless, there are several disadvantages of microstrip antennas. Narrow operation bandwidth is the main disadvantage. The bandwidth of the basic patch antenna is usually 1 – 3%. The bandwidth of the antenna depends on the patch shape, dielectric constant, the thickness of the substrate and the resonant frequency [7]. The design of microstrip antennas suitable for new WLAN to achieve dual-frequency or multi-band is developed in recent years.

Microstrip dipole is a narrow microstrip conductor on the true side of the substrate, which is interrupted by a feeding gap. Microstrip dipole or printed dipole antenna has been applied in communication devices such as notebook computer and access point for WLAN operations [8-9].This Type of microstrip dipole antenna usually has a narrow width and in this case it can be integrated at the access point of WLAN application

II.MICROSTRIP DIPOLE ANTENNA DESIGN

The approach proposed in this paper is to design microstrip dipole resonance at 2.4 GHz frequency band. Figure 1 shows the structure of a microstrip dipole of length ***L***, width ***W*** and gap ***G*** that were used in simulation. The proposed antenna element is printed on a FR4 substrate with a dielectric constant of 4.7, a thickness of 1.6 mm and a conductor loss of 0.019. The two hatched rectangular pieces in Figure 1 are copper on the top of the substrate. Each of it is connected with the microstrip bend. The gap between the two pieces is ***G*** and the microstrip dipole is fed at the middle of the gap. One piece of the hatched is fed with connector and another one is connected to the ground.

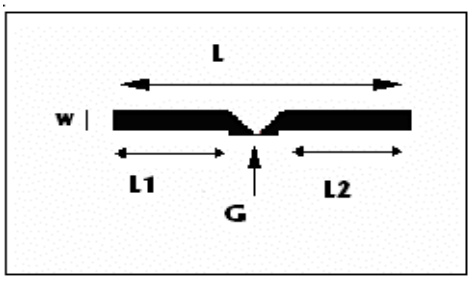


Figure 1: Microstrip Dipole Layout

Microstrip dipole of rectangular hatched or rectangular geometry as shown in figure 1 can be designed for the lowest resonant frequency using transmission line model. The formula to calculate the value of λ, L_2 and W can be found through formulation as follows [10]:

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The effective dielectric constant (ε_{eff}) constant of a microstrip line:

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12\,d/W}}\right) \quad \textbf{(1)}$$

Where

ε_r = Dieletric Constant
d = substrate thickness
W= width of microstrip line (Approximation is made for the simulation)

The length (***L*** $_1$ and ***L*** $_2$) of microstrip line using formula:

$$\lambda = \frac{c}{f\sqrt{\varepsilon_{eff}}} \quad \textbf{(2)}$$

Where **λ**= wavelength
C= velocity of light
f = frequency

Thus $L_1 = L_2 = \lambda/4$

The length of each hatched rectangular is about quarter-wavelength. In this case the length of rectangular hatched, ***L1=L2= λ/4***=17 mm and the gap between the two pieces, ***G*** = 0.9mm. At the designed frequency, approximation of the width ***W*** is made and it is equal to 2.90 mm. Overall, the length of the dipole is about, ***L*** = 40mm. In addition the microstrip bend is added between the two rectangular hatched which has length and width is equal to 2.9 mm. The photograph of the fabricated microstrip dipole prototype can be shown in figure 2.

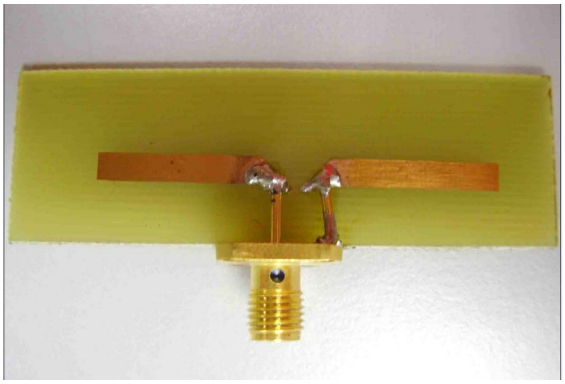


Figure 2: Fabricated Microstrip Dipole.

The design procedure of microstrip dipole antenna design can be carried out in a few steps as follows;

- The resonance frequency is chosen and for this case resonance frequency at 2.4GHz is chosen.
- Calculate the correct dipole dimension (L_1, L_2 and W) by using microstrip transmission line formula.
- Connect the rectangular hatched with microstrip bend and chooses the suitable gap G between the two hatched pieces on the substrate.
- The gap between the two traces is G and the microstrip dipole is fed at the middle of the gap.

III. Result and Discussion

The result of microstrip dipole antenna has been discussed in term of bandwidth response, radiation pattern characteristic and cross polar isolation relative to monopole antenna. Also, the return loss for both simulation and measurement of microstrip dipole is discussed

A. Input Return Loss

The measurement and simulation result of input return loss for the microstrip dipole antenna is shown in figure 3. The bandwidth from the measurement result is 22.99 % and the bandwidth using simulation result is 19.03%. The experimental result show the frequency has been shifted up slightly and the bandwidth is much greater than the simulation result. The resonance of the antenna can be seen by observing the dip in the return loss. The simulation results give a good approximation for the measurement even though the bandwidth is much lower than the simulation results.

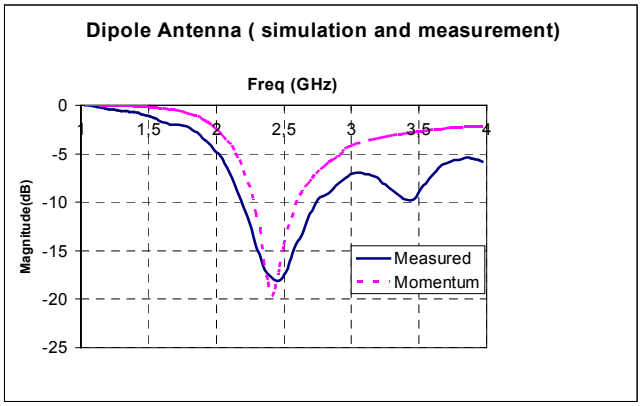


Figure 3: Input Return Loss for Microstrip Dipole Antenna.

Figure 4 shows the measurement result of input return loss for monopole and dipole antenna. The bandwidth of monopole antenna from measurement result is 8.31%. It shows that the microstrip dipole offer higher bandwidth compare to the monopole antenna.

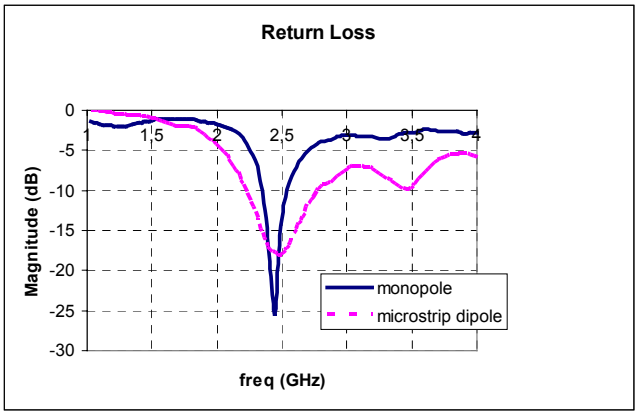
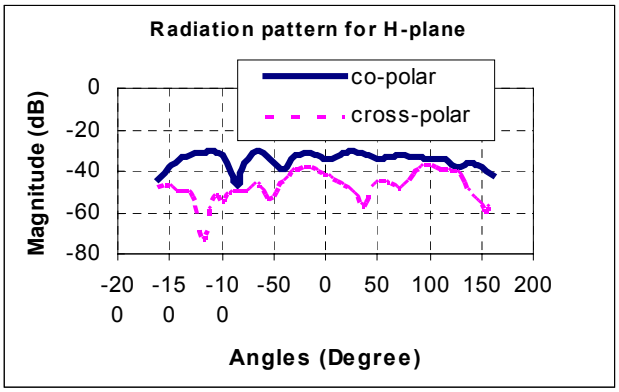


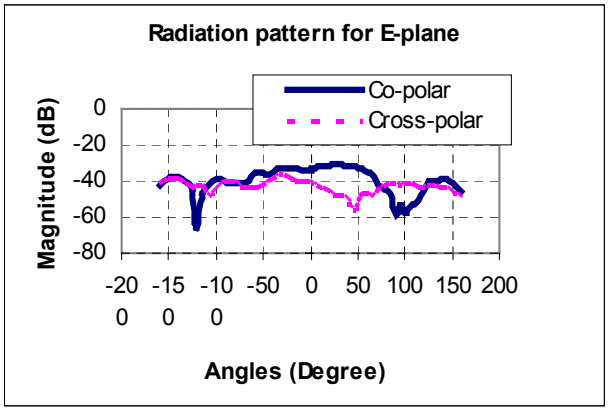
Figure 4: Input Return Loss for dipole and monopole antenna.

B Radiation Pattern

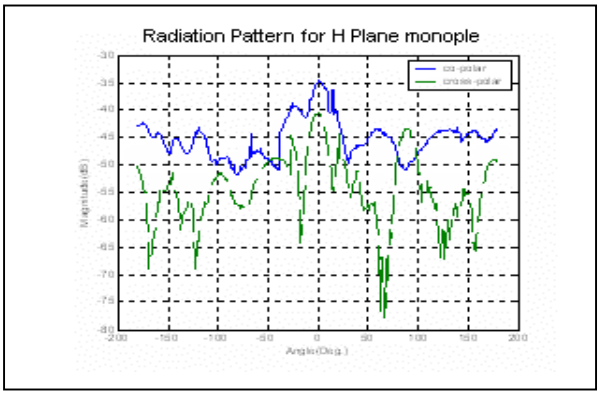
Figure 5(a) and 5b) shows the radiation pattern of the microstrip dipole antenna for H Plane and E Plane at 2.4 GHz. The radiation pattern is in the broadside direction. The cross polar isolation for E Plane is 17.32 dB and for H Plane is 15.62 dB. The HPBW for E Plane is 60° and H Plane is 75°. Figure 5(c) and 5(d) show the radiation pattern of the monopole antenna for H Plane and E Plane. The cross polar isolation for monopole antenna in E Plane is 6.13 dB and for H Plane is 13.21 dB. The HPBW of the monopole antenna for E Plane is 15° and H Plane is 21°.



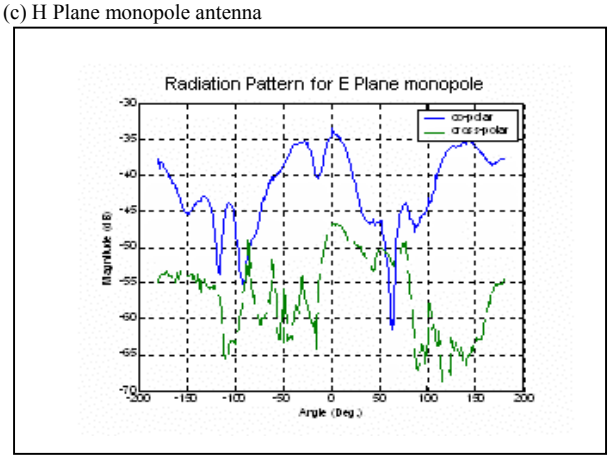
(a) E Plane microstrip dipole antenna



(b) H Plane microstrip dipole antenna



(c) H Plane monopole antenna



(d) E Plane monopole antenna

Figure 5: Radiation Pattern for microstrip dipole and monopole antenna.

CONCLUSIONS

A low cost microstrip dipole antenna for WLAN operations in the 2.4GHz band has been proposed. The proposed antenna has a narrow width, and is easy to implement. By having its dipole near one half wavelengths, the antenna radiates bidirectional in the E-plane. The dipole was prototyped and tested. Measurement and simulation result was compared. The bandwidth for microstrip dipole is 14.68% greater than monopole antenna. The cross-polar isolation of the microstrip dipole antenna is in the range of 3 to 17.32 dB. The maximum cross-polar isolation can be seen at H Plane. The HPBW for microstrip dipole is 60º for E plane and 75º for H plane

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March 25, 1969 W. C. BROWN ET AL 3,434,678

MICROWAVE TO DC CONVERTER

Filed May 5, 1965 Sheet 1 of 3

FIG. 1

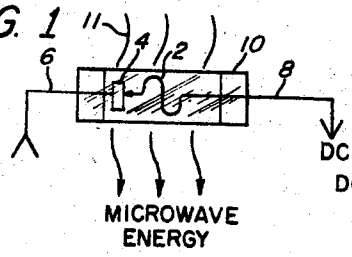


FIG. 2

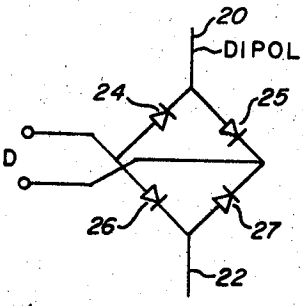


FIG. 3

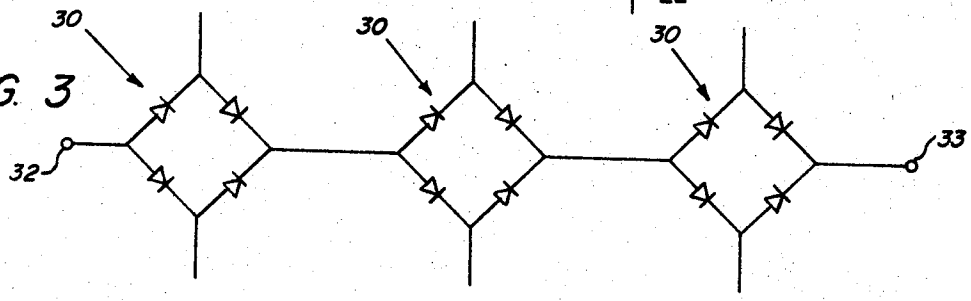
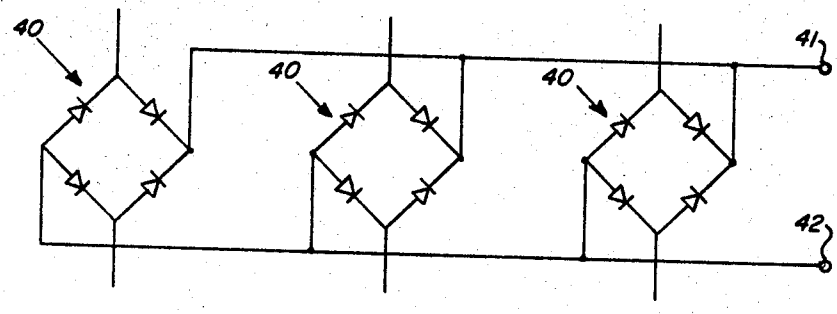


FIG. 4



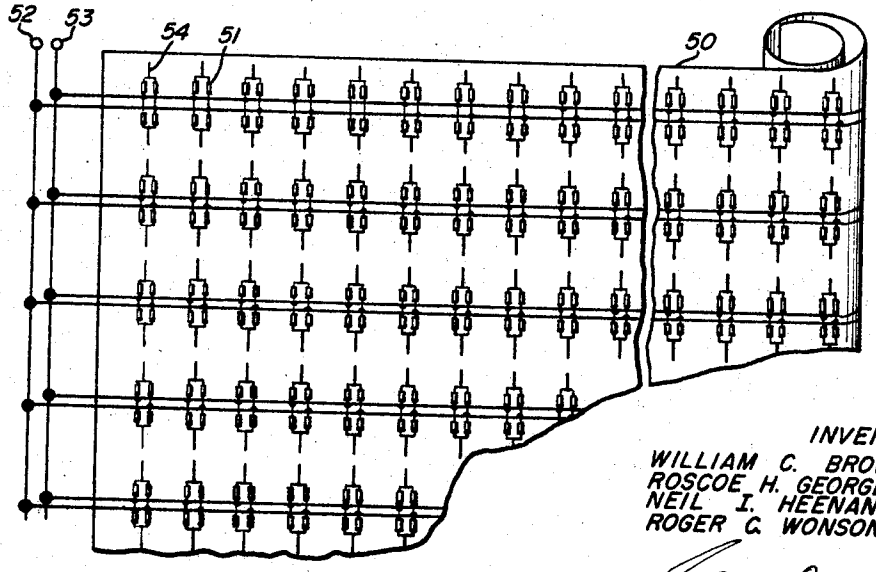


FIG. 5

INVENTORS
WILLIAM C. BROWN
ROSCOE H. GEORGE
NEIL I. HEENAN
ROGER C. WONSON

BY Edgar O. Cook

ATTORNEY

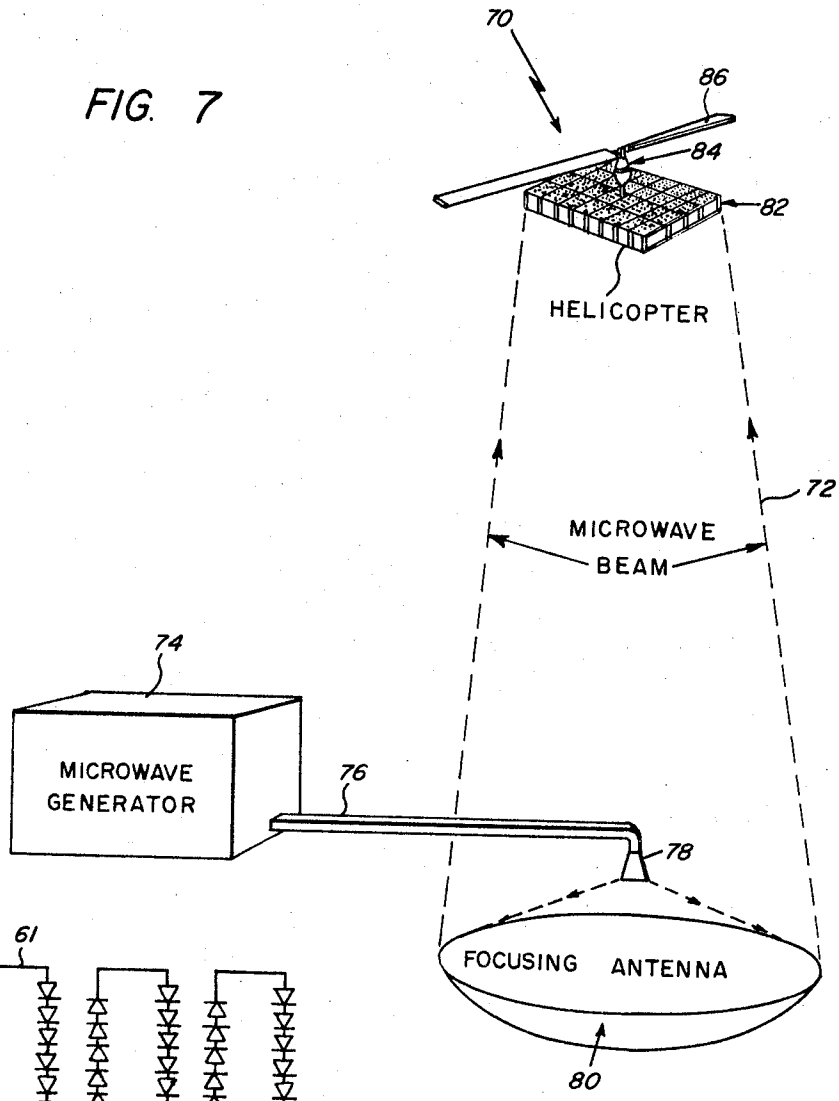
March 25, 1969 W. C. BROWN ET AL 3,434,678

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FIG. 7



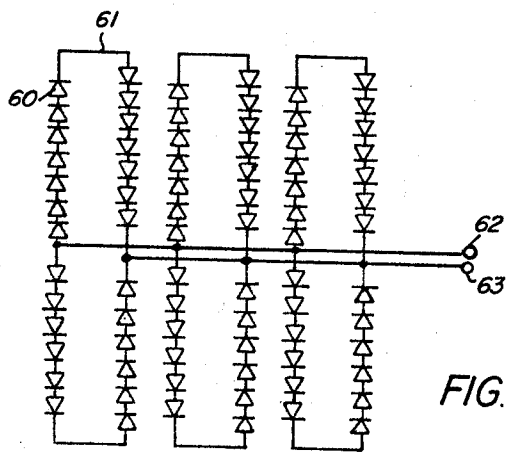


FIG. 6

INVENTORS
WILLIAM C. BROWN
ROSCOE H. GEORGE
NEIL I. HEENAN
ROGER C. WONSON

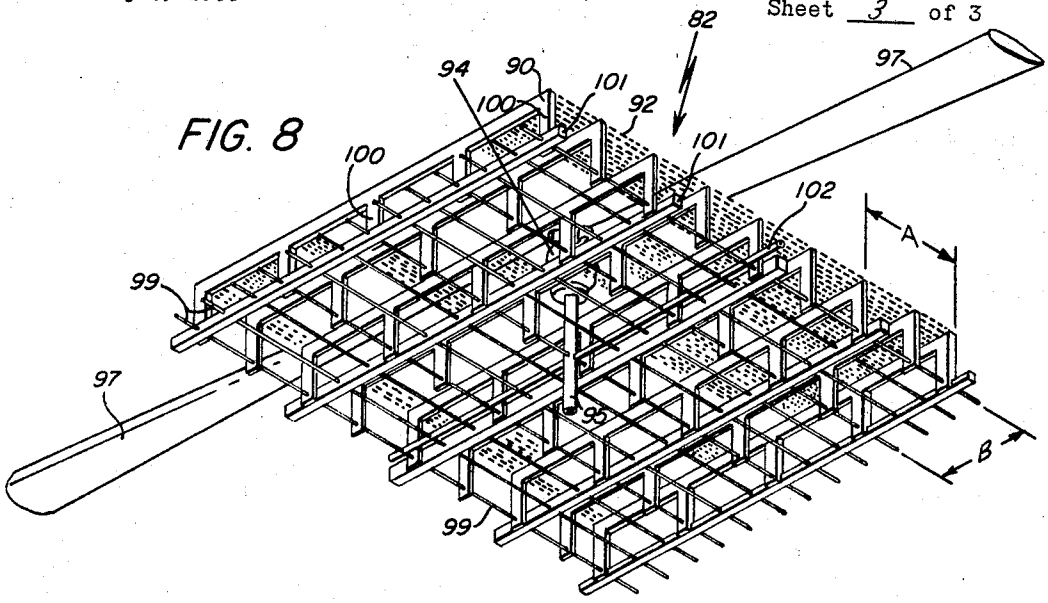
BY Edgar O. Lost
ATTORNEY

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FIG. 8



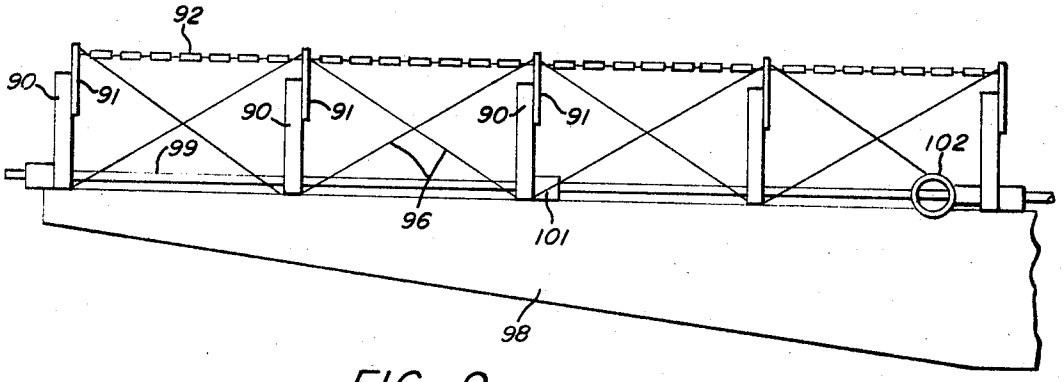


FIG. 9

INVENTORS
WILLIAM C. BROWN
ROSCOE H. GEORGE
NEIL I. HEENAN
ROGER C. WONSON

BY Rodger O. Root
ATTORNEY

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Patented Mar. 25, 1969

3,434,678

MICROWAVE TO DC CONVERTER

William C. Brown, Weston, Mass., Roscoe H. George, West Lafayette, Ind., and Neil I. Heenan, Needham, and Roger C. Wonson, Beverly, Mass., assignors to Raytheon Company, Lexington, Mass., a corporation of Delaware

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Int. Cl. B64g 1/00
U.S. Cl. 244—1
3 Claims

ABSTRACT OF THE DISCLOSURE

A combined antenna and conversion mechanism for reception of beamed high frequency electromagnetic energy in space including a large array of unidirectional current semiconductor rectifier devices. A self-supporting space vehicle utilizing the rectified DC electrical energy for propulsion is disclosed in an illustrative embodiment.

The present invention relates in general to the transfer of energy by means of an electromagnetic wave beam and more particularly to interception and rectification of such energy into low frequency electrical DC energy with a high degree of efficiency.

Improved technology in the field of microwave energy generation at superpower levels has resulted in the realization of electrical energy transmission over considerable distances for remote energization of devices or vehicles without the aid of wires. The transmission of microwave electromagnetic energy into space has been commonly employed in the radar pulse echo systems for the detection and orientation of desired objects within a predetermined scanning range of a transmitting antenna. Beams of a similar nature may now be employed for other useful purposes and the advantages attendant the utilization of electromagnetic energy in the microwave region in contrast with other wavelengths may now be enumerated.

Microwaves have been generally defined as high frequency radio waves whose wavelength is less than 30 centimeters, with a lower wavelength limit on the order of 1 millimeter sometimes being applied to what is commonly referred to as the "microwave region." The superiority of high frequency microwaves is due in part to the fact that it is generally desirable to focus the transmitted energy so as to achieve a high power density at a remote point or area with respect to a given power source. In accordance with the laws of optics, the sharpness of the microwave beam produced by a transmitting antenna varies as the ratio of antenna dimensions to the wavelength of the transmitted energy. Therefore, for a given or desired power density or beam sharpness, a decrease in the wavelength of the transmitted energy permits a corresponding decrease in the dimensions of the antenna. From the standpoint of mechanical considerations, it is desirable to employ small antennas and other components, and it is therefore advantageous to employ high frequency energy of very short wavelength. In addition, the difficulties encountered in long wave transmission as a result of natural and man-made interference or noise do not occur with any appreciable significance at microwave frequencies. Further, in aerospace applications with considerable distances separating the transmitter at an earth or mother planet location and the employment of shorter wavelength beamed energy is preferred since longer wave signals will generallly be reflected at certain altitudes by reflecting layers in the atmosphere.

In view of certain losses due to absorption which may occur in the atmosphere, microwaves in the region having the approximate bounds of 2 and 30 centimeters are

readily adaptable to the convenient radiation of power to remote points without the utilization of wires. The preferred wavelengths are of the order of 5 or 10 centimeters to provide efficient focusing with existing transmitting antenna systems which may be maintained at a reasonable size. An illustrative device of the superpower high frequency microwave generators operative in the desired band is the so-called Amplitron which is an amplifier having a broad bandwidth and excellent performance characteristics for the focusing of the beam. Such devices are capable of producing 15 or 20 kilowatts of average continuous wave power in the neighborhood of 10 centimeters in wavelength with capabilities expected in the region of 500 kilowatts or more average power with 50 megawatts peak power. A complete description of such devices may be had by referring to Patent No. 2,933,723 issued Apr. 19, 1960 to William C. Brown and assigned to the assignee of the present invention.

With microwave energy capable of being generated and directed over longer distances conversion of such high frequency electromagnetic energy is of paramount concern. One conversion mechanism in the prior art involves direct conversion of such energy into heat which may then be utilized directly or indirectly for propulsion or generation of flight-producing forces. Examples of such devices for heat energy exchange as well as space vehicles utilizing such energy may be noted in Patent No. 3,174,705, issued Mar. 23, 1965, to D. Schiff et al., as well as U.S. Letters Patent No. 3,083,528, issued Apr. 2, 1963 and No. 3,114,517, issued Dec. 17, 1963, to William C. Brown. The heat exchanger method of conversion of electromagnetic energy into useful power is limited by the overall efficiencies of approximately 25 percent in the conversion of heat into mechanical or electrical work. Desirable, therefore, would be the direct rectification of the high frequency electromagnetic energy into low frequency electrical energy for the operation of many useful aerospace devices as well as systems.

The present invention has for its primary object the conversion of high frequency electromagnetic energy in the microwave region directly into low frequency electrical energy.

A further object of the present invention is the provision of a combined nondirectional receiving antenna and microwave electromagnetic energy to low frequency electrical energy conversion means in a unitary structure.

A still further object of the present invention is a provision of a new and novel combined nondirectional receiving antenna and microwave to DC energy converter for aerospace applications.

Another object of the present invention is the provision of a new and novel nondirectional receiving antenna and microwave to DC energy converter having a high degree of efficiency.

Still another object of the present invention is the provision of a new and novel aerospace vehicle with nondirectional receiving antenna and microwave to DC energy converter means with said vehicle being capable of being supported by its own energy generation means at a distance spaced apart from the power generation means.

In accordance with the teachings of the present invention, the above and other objects are achieved by the employment of efficient unidirectional microwave power rectifiers and dipole antenna means. Such rectifying devices, while being individually limited in power-handling capabilities, normally in the order of fractions of watts, have been found to be highly efficient means for the rectification of microwave power when assembled in large numbers in various arrays. It is interesting to note that the observed collective efficiency was on the order of 40 to 70 percent. In an illustrative embodiment, point-

contact semiconductor diodes were arranged in four arm bridge connected networks with the networks interconnected in various configurations such as series, parallel and series-parallel.

In discussing aerospace applications, an additional problem is encountered in the beaming of microwave energy to a remote point and the interception and utilization of such electrical energy. In such applications the advantages of a vehicle which may be maintained in space for indeterminate periods of time without employing a local fuel source are readily apparent. Such devices could readily provide communication networks, surveillance functions using radar techniques along with numerous other functions. The acapture of the beamed high frequency electromagnetic energy raises the need for an efficient antenna means capable of intersecting the beam at high altitudes. Conventional techniques employed in microwave radar usage such as receiving antenna horns are capable of intersecting only a small portion of the beam energy and add considerable weight in applications involving heavier-than-air vehicles. In an exemplary embodiment of the invention a space vehicle, namely a helicopter, is disclosed for either moving flight or a stationary location with self-supporting electrically operative propulsion means. The semi-conductor diode rectifier arrays have been demonstrated to fulfill the receiving antenna functions as well as the electrical energy rectification means in a highly efficient manner. Such combined antenna and rectifier means has also assisted in reduction of the weight problem in airborne devices. Further, it has provided a nondirectional means for the interception of the microwave energy to thereby reduce the problems of focusing inherent in prior art directional horn type receiving antennas.

With the above features, advantages and objects in mind the invention will now be described by reference to the following detailed description together with the accompanying drawings in which:

FIG. 1 is a perspective view of an illustrative diode rectifier;

FIG. 2 is a schematic circuit diagram of a bridge connected diode network with dipole antenna means;

FIG. 3 is a schematic circuit diagram of a plurality of bridge connected networks arranged in series;

FIG. 4 is a schematic circuit diagram of a parallel bridge connected network array;

FIG. 5 is a perspective view of an illustrative embodiment of a combined antenna and rectifier array in a folded or rolled up configuration;

FIG. 6 is a schematic circuit diagram illustrating the bridge connected diode array incorporated in the aerospace vehicle shown in FIG. 7;

FIG. 7 is a schematic representation in elevation illustrative of a heavier-than-air aerospace vehicle incorparating the structure of the present invention;

FIG. 8 is a perspective view of the aerospace vehicle embodiment as viewed from the under portion thereof; and

FIG. 9 is an enlarged partial view in elevation of a portion of the illustrative embodiment shown in FIG. 8.

FIG. 1 illustrates a point-contact semiconductor diode rectifier of the type employed in radar microwave receiver apparatus to rectify returned radar pulses. Any of the high burnout semiconductor diodes having high rectification characteristics are preferred and are commercially available, such as the 1N82 or 1N830. The rectifying junction is formed by whisker element **2** contacting the semiconductor element **4** respectively connected to leads **6** and **8**. Silicon is preferred over germanium for element **4** because of its ability to operate at higher temperatures and thereby handle higher powers. Envelope **10** houses the rectifying elements and may be of a hermetically sealed dielectric material or combination metal and ceramic composition. The inherent characteristic of such diode rectifiers is that the microwave energy is intercepted and rectified in a unidirectional manner and the line **11** indicate pictorially the rays of the beamed electromagnetic microwave energy in a plane normal to the envelope. In FIG. 2 a full-wave bridge connected diode network is illustrated with the forward direction of the rectified DC electric current indicated by the direction of the arrow symbols. The network shown consists of half-wave dipoles **20** and **22** each terminated with a diode rectifier element **24** to **27** in an arm of the bridge connected network. The dipole elements **20** and **22** are of the half-wave configuration and may be spaced apart from each other a one-half wavelength at the frequency of the beamed electromagnetic energy.

Referring now to FIG. 3, an array of bridge connected diode networks each with the half-wave dipoles are shown connected in series. Each network is referred to by the numeral **30** and is similar in the bridge connections to the single element network shown in FIG. 2. The DC output of the collective rectified energy is coupled by means of terminals **32** and **33**. In FIG. 4, a similar number of individual bridge connected diode-dipole networks are shown connected in a parallel array. Each network is indicated by the numeral **40**, and the output terminals are indicated as **41** and **42**.

Any number of diode-dipole networks may be provided and in FIG. 5 such a multi-element array is illustrated by mounting on a flexible material **50** which may be rolled or folded into any desired package or enclosed within a capsule to be launched and released at a predetermined point in space. Any flexible material which is pervious to electromagnetic energy is preferred. The total power desired would be the determining factor in a number of individual diode-dipole elements required. In this embodiment, the bridge connected networks **51** are connected in parallel to the output load indicated by terminals **52** and **53**, and representative measurements of electrical characteristics have shown that approximately five watts of DC electrical energy is realizable for each square foot of area of the combined antenna-rectifier. While the dipole elements **54** have been indicated in a particular array, it is within the scope of the invention to stagger the placement of such dipoles to increase the over-all efficiency of the antenna-rectifier.

To further increase the DC powder output, the full-wave bridge connected networks are preferably arranged with a plurality of diodes in series in each arm of the bridge. An illustrative schematic circuit diagram of such a configuration is shown in FIG. 6 wherein seven diodes **60** are shown in each arm of the bridge circuit and are connected in series for a total of twenty-eight diodes in each bridge network. The dipole members will then be the substantially U-shaped end portions **61** at the ends of each brace of seven diodes. In the illustration three such twenty-eight diode bridge networks are shown connected in parallel to terminals **62** and **63**. This closer spacing and compact arrangement has been shown to be a source of improved power output and is capable of a high degree of reliability through the redundant nature of the parallel series connections within each bridge network. If one of the diode rectifiers fails to function the over-all voltage drop across this element would be divided among the six remaining diode rectifiers. If any of the connecting wires between the diode elements should break, the adjacent arms of the other bridge assemblies would take the additional load due to the close proximity of the respective arms to each other. In addition, it is possible to have a number of open connections or inoperative diodes dispersed throughout the array without any serious impairment in performance.

In relation to the array concept to be hereinafter described it may be stated that within a six inch square area ten such individual bridge networks each containing twenty-eight diode rectifiers for a total of 280 diode rectifiers may be deployed in such a manner as to provide

maximum exposed area for each diode as well as the connecting leads. Such an arrangement will be hereinafter referred to as a "module" and a DC output in excess of fourteen watts has been measured for such a module. Any number of such modules could be connected provided for a desired power yield and this module concept readily lends itself to use in certain aerospace applications now to be described.

In FIG. 7 a propelled type of space vehicle **70** is shown wholly supported by means of the transfer and rectification of continuous wave electromagnetic energy via a microwave beam **72**. The source of the microwave energy which may be of the Amplitron type device as described in the aforementioned issued Patent No. 2,933,723 is indicated as **74**. This energy is fed by waveguide means **76** to a transmitting horn **78** to illuminate an ellipsoidal beam forming focusing antenna **80** for the transmission of the microwave beam **72**. It will be appreciated by those skilled in the art that the representations of the microwave generation and transmitting antenna means are pictorial representations to illustrate the usage of the invention in diagrammatic form and the present invention is not limited to any particular source of microwave energy or transmitting antenna assembly. It may be stated the reflector of the antenna assembly is considerably larger than most of the reflectors of the prior art in order to focus a large amount of the microwave power at high altitudes for use in the transfer of energy to space vehicles. Such antenna assemblies may be partially supported in a large hollowed area on the earth's surface or other convenient means of support.

The space vehicle or helicopter **70** can be described as a main body member supporting antenna-rectifier means **82** including a large number of the so-called modules connected together and rigidly supported in a planar parallel array. A motor **84** is supported by the combined body member and the receiving antenna-rectifier means and actuates the rotor **86** of conventional design employed in such self-propelled hovering vehicles. The disclosed vehicle provides for the illumination of the planar array of the semiconductor diode dipole elements by the microwave beam and the direct conversion of the microwave power transmitted by the beam into usable electrical energy for the self-propulsion of the device without any local fuel supply being required.

FIGS. 8 and 9 illustrate a space vehicle **82** comprising a plurality of the combined receiving antenna-rectifier module means for interception and rectification of the electromagnetic microwave energy beam emanating from an earth or mother planet source. A planar array of the antenna-rectifier modules is mechanically supported by means of structural members **90** of any lightweight wood or metal. Insulators **91** positioned coextensive with the members **90** support the diode rectifier array and avoid interference with the receiving and electrical performance characteristics by the structural support members. Carrying forward the module concept of 280 diode rectifiers to provide an approximate power output of 14 watts, it was noted that any number of such modules may be coupled together since the individual module outputs are relatively insensitive to a wide range of load resistances connected to the common output terminals. To achieve the desired electrical output of approximately 120 volts and 250 watts of power, subgroups of four modules each were assembled and parallel connected with an approximate 30 volts available for each subgroup. Four such subgroups were series-connected to result in a total of 4,480 diode rectifiers or 16 modules assembled in a two foot square self-supporting planar parallel array structure. The individual diode rectifiers connected in each arm of the bridge network are indicated by the numeral **92**. An exemplary module configuration would extend within the area delineated by the dotted lines and reference letter A on one side and similar dotted lines and reference letter B on the other side.

A motor **94** is connected to the DC side of the overall array and may be additionally supported by tubular member **95**. A shaft and propulsion means consisting of rotor blades **97** provide for the upward lift of the overall vehicle for the self-supporting of same in space applications. Additional structural support such as interlaced rigging **96** of a high tensile strength material such as nylon or steel wire, as well as bracing member **98**, may be employed for strengthening of the body means to withstand the vibrational forces and downwash from the propulsion means.

In accordance with the well known technology of microwave transmission the combined array of diode rectifiers and propulsion means presents a specific load impedance which must be suitably matched to the transmitted microwave energy beam to result in maximum efficiency. In aerospace applications a mismatch of approximately ten to one may be evident. Matching of the load impedance to a value of approximately 377 ohms as the free space value will be provided by a plurality of coplanar parallel metallic rod members **99** disposed in a grating array in front of the diode rectifiers a predetermined distance. Rod members **99** are linearly disposed and extend in a similar direction as the assembled diode rectifiers. A selected frontal spacing of one-quarter of the wavelength of the microwave frequency being transmitted has been experimentally determined to be suitable for impedance matching purposes. An approximate spacing of two inches between the respective members was preferred for a selected microwave frequency of 2,450 megacycles. Each of the members **90** are provided with lateral sections **100** to support the elongated bar members **101** which in turn maintain the rod members **99** in the desired position. A tubular member **102** of a lightweight metal may also be provided to combine with the motor support member **95** for structural support.

The combined antenna-rectifier array provides a source of electrical energy to render any space vehicle self-supporting. The diode rectifier elements when assembled in the antenna array have been found to be nondirectional with respect to interception of the beamed microwave energy. This represents a large step forward in the utilization of high power microwave energy over the prior art horn-type receiving antennas which must be accurately focused and pointed in a particular direction for the reception of any energy. The connections between the respective members of the diode rectifier array and deployment in the parallel configuration serves to provide maximum exposed area. Such connections and in particular the end loop portions adjacent the terminus of each arm of the bridge networks serves as an efficient dipole for the interception of the microwave energy.

Although it is not intended as a full explanation of the high degree of efficiency attained with the disclosed antenna-rectifier array, it is believed that the whisker elements within the semiconductor diodes themselves are a contributing factor and may function as additional dipole elements. The disclosed embodiment functioned efficiently when illuminated by microwave energy generating a vertically polarized beam. Hence, an efficient and light weight energy conversion apparatus is disclosed which may be self-supporting without the requirement of a large local fuel supply payload.

It may be within the purview of the invention to use the available rectified electrical energy for performing many functions in addition to the actuation of the propulsion means. Hence, communications' payloads may be maintained at predetermined positions in space in a hovering attitude utilizing a portion of the electrical energy available. Relay signals to other such vehicles or return signals to ground stations would then be within the realm of possibility. Such available energy may also be employed for servomechanisms, stabilizing and countertorque systems for the navigation of such vehicles.

The electrical efficiencies realized with the combined

receiving antenna and rectifier means have also provided certain weight advantages over other energy converters in aerospace applications. Examples of such converters would be heat exchangers or solar cells. In comparison to the present invention where five to eight pounds per kilowatt of energy realized is a normal characteristic, other energy conversion means weigh in the vicinity of 150 pounds per kilowatt of realizable energy. The inherent advantages of the present invention are therefore apparent. While the technology in the diode rectifier art is being continually advanced, new diode power rectifiers as well as integrated circuit techniques are readily available to future configurations of the present invention. The so-called Schottky barrier diodes could be employed to produce combined antenna-rectifier means weighing even less than two pounds per kilowatt of available energy.

Although the foregoing detailed description has referred to DC power rectification it will be evident that with suitable circuit components low frequency AC energy may also be made available. In addition, other propulsion means may be readily substituted using electrical energy. The embodiments disclosed herein are illustrative only and other modifications or alterations will be apparent to those skilled in the art which do not depart from the scope of the broadest aspects of the present invention as defined in the appended claims.

What is claimed is:

1. A space vehicle comprising:

body means;

said body means including spaced structural support members;

combined antenna and DC electrical energy rectification means for the interception and rectification of incident high frequency electromagnetic microwave energy carried by said support members in a planar parallel array;

said rectification means comprising a plurality of four arm full-wave bridge connected rectifier circuit networks each having a plurality of unidirectional semiconductors in each arm;

said networks being electrically interconnected to common output terminals;

electrically operable propulsion means comprising a motor and rotor members carried by said body means and connected to said terminals for the utilization of said rectified DC energy; and

means for matching the load impedance of said combined antenna and electrical energy rectification means to the incident microwave energy.

2. A space vehicle according to claim 1 wherein said load impedance matching means are arranged in a coplanar array coextensive with said antenna and energy rectification means array, and spaced therefrom a distance of approximately one-quarter of a wavelength at the frequency of the microwave energy.

3. A space vehicle according to claim 2 wherein said load impedance matching means comprise a plurality of parallel disposed elongated metallic members.

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RODNEY D. BENNETT, *Primary Examiner.*

MALCOMB F. HUBLER, *Assistant Examiner.*

U.S. Cl. X.R.

307—151; 318—16; 321—27; 325—494; 343—100

A METHOD TO LISTEN TO QRSS SIGNALS!

(2012)

KLIK HIER VOOR DE NEDERLANDSE VERSIE



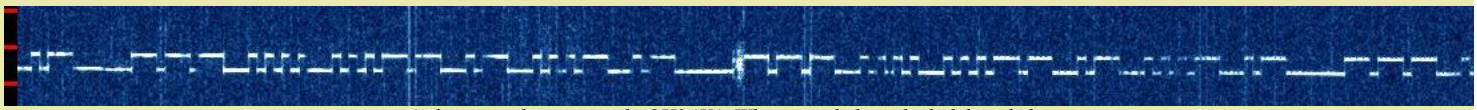
The method to listen to QRSS signals is...
An old tape recorder with variable speed!

The simple method to listen to QRSS signals
Very sensitive QRSS reception was already possible before the computer age! Indeed by ear, with the same sensitivity as with our computers! That is possible with a tape recorder with variable speed. As an example we take a QRSS signal with a frequency of 10140.050 kHz. The receiver is tuned 45 Hz lower at 10140.005 kHz. Then the QRSS signal at the audio output of the receiver, has a frequency of 45 Hz. We record this signal with the tape recorder with a very low speed of 2.4 cm/sec. And then we play this signal with a 16x higher speed of 38 cm/sec. All frequencies are 16x higher now. Our QRSS signal of 45 Hz is now audible with a tone height of 16x45 = 720 Hz! The QRSS band, 100 Hz wide, has become 1600 Hz wide now. The noise will be spread over a 16x wider frequency range, the signal to noise ration has been increased 16x! And the usual dot length of 3 seconds for a dot is 16x shorter or 0.18 seconds. The usual shift of 5 Hz has increased 16x and is now 80 Hz. The QRSS morse signal has become a normal audible morse signal of approximately 6 words per minute!



We can improve the system even more by adding an audio filter.
That filter is 10 Hz wide (40 Hz - 50 Hz), but because we play 16x faster, it becomes 160 Hz wide.

Some reception results
Here some reception results. On the pictures, you can see the received signals. And below the picture is the link to an audio WAV file where the signals of the picture can be heard.



A clear signal to start with. OH3AVA. When you click on the link here below,
you can hear this signal. It is played 16x faster than the original signal.

Listen to OH3AVA

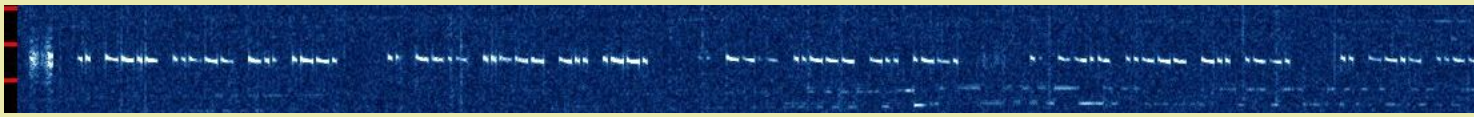
Not bad, even the weak part in the picture is still audible!!!
Another station:



GJ7RWT.
Here below the link to listen to the signal.

Listen to GJ7RWT

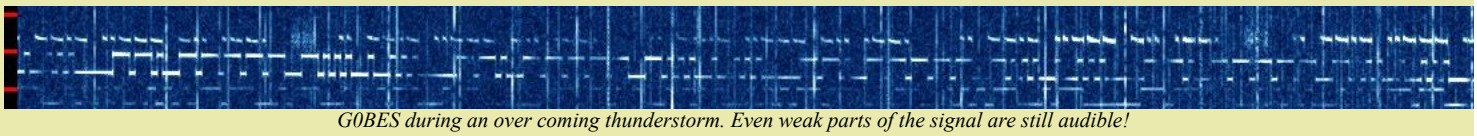
And at the same time, IQ2DP was audible:



IQ2DP. Even the very weak "i" is still audible!
Here below the link to listen to the signal.

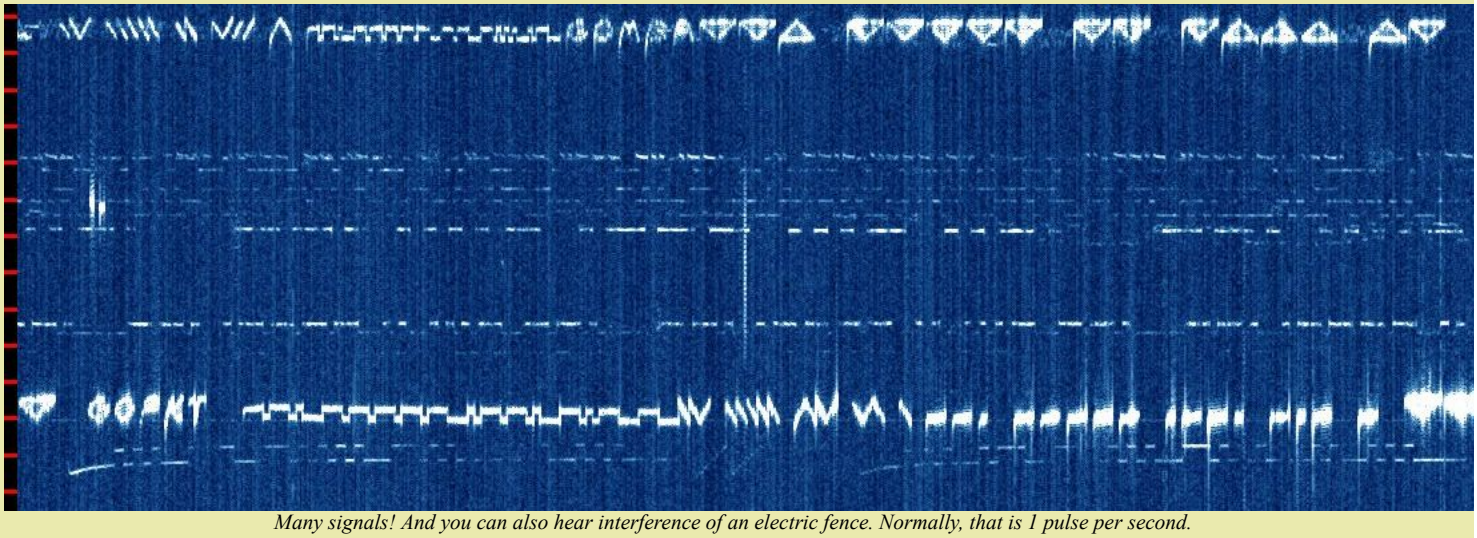
Listen to IQ2DP

And 22 June 2012, G0BES was audible during an over coming thunderstorm:



G0BES during an over coming thunderstorm. Even weak parts of the signal are still audible!
Here below the link to listen to the signal.

Luister naar G0BES



Many signals! And you can also hear interference of an electric fence. Normally, that is 1 pulse per second.
But you do hear 16 pulses per second, because we play the signal 16x faster!
Here below the links to listen to the signals.

Listen to G0PKT on 1500 Hz, a very strong signal!

And G0MBA on 1605 Hz, hear how Hell sounds!

And G1IVG on 1528 Hz, a difficult visible signal, but excellent audible!

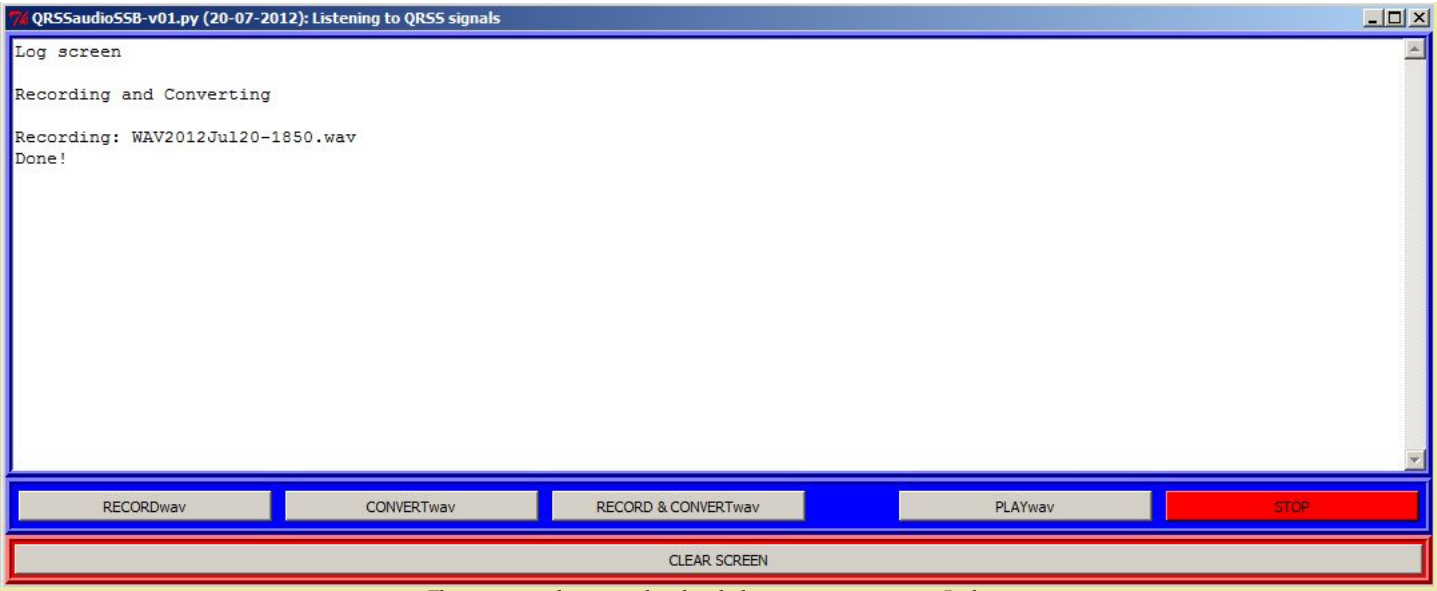
And G4JVF on 1550 Hz. Also a difficult visible signal, but excellent audible!

And SA6BSS at the bottom of the picture on 1490 Hz, very difficult visible and close to the strong signal of G0PKT, but audible!

And without 10 Hz audio filter, you do hear all signals at the same time, but on different tone heights.

REALISATION

The hardware
But I did not have a tape recorder anymore. And I did never have a Revox as you can see on the picture, they were well above my budget. And my receiver did not have an audio output of 45 Hz. The QRSS band in the 30 meter band is at the audio output of the receiver in the audio band of 1495 Hz - 1595 Hz. But we can simulate the tape recorder with a PC. We do make an audio recording of the receiver output. We can use this recording again and again. A QRSS signal in the audio band 1495 -1595 Hz is down mixed to 45 Hz and filtered with a 10 Hz wide audio filter. And then a WAV audio file is made that plays 16x faster than the original recording. Good to realize with the free software language Python.



The tape recorder is simulated with this program, written in Python.

The software-tape recorder
It works nicer than an old tape recorder and also does something extra than just recording and playing. A QRSS signal in the audio band of 1495 Hz - 1595 Hz is also down mixed to 45 Hz. And the low frequency band filter is also in the software. Frequenties and the bandwidth of the filters are variable.

RECORDwav
Continuous recordings of 20 minutes are made. These recordings are stored as audio WAV files with the date and time as the file name. This goes on till you press the stop button.

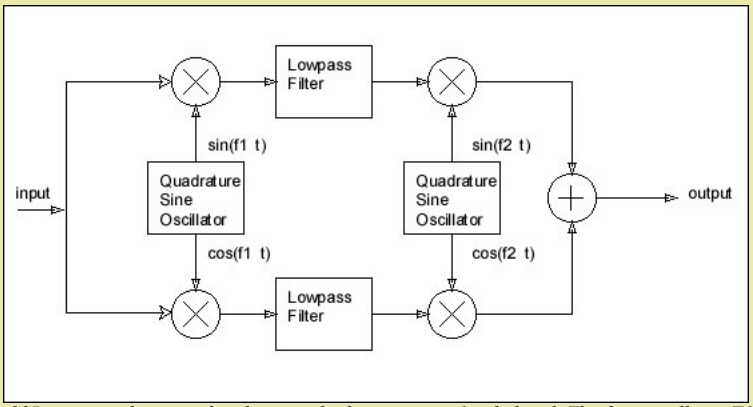
CONVERTwav
The recorded WAV files can be converted to 16x faster playing WAV files.
Asked is which filter you want to use. For 1 QRSS signal, you do use filter number 1, the FIR filter and you do select a bandwidth of 10 Hz. But when you want to listen to the whole band, then select the better filter 2, and IIR filter with a bandwidth of 100 Hz.
If the FIR filter 1 is selected, the bandwidth will be asked. The value of 10 Hz is good for 1 signal, but you can also try other values. However, the IIR filters do have fixed bandwidths and they are only correct if the sample rate is set to 6000 samples per second.
Then the frequency of the QRSS signal that has to be converted is asked. Or when you want to convert the whole QRSS band, the central frequency of the QRSS band.
And then the frequency where to the QRSS signal has to be down mixed. Normally that is 45 Hz, so with a 16x faster playing speed, you will hear a tone of 720 Hz.
Then the new speed will be asked, 16x is the default value.
And finally, you can increase the volume of the converted WAV file. Always easy when you do receive weak signals.

RECORD & CONVERTwav
I never used this option. But perhaps that someone else can do something with it.
Continuous recordings of 20 minutes will be made. After every recording, a converted WAV file will be made. When you have chosen a reception bandwidth of 100 Hz (filter 2) and 70 Hz as the frequency where the signal has to be down mixed to, you can hear the whole band at once and hear how the activity is.

PLAYwav
And for completeness, a PLAYwav button has been added, but it is better to use the standard audio player of your PC.

How to use
At the same time with the normal QRSS decoding software like ARGO or LOPORA, also this program runs in the RECORDwav mode on the same PC. When something special is visible on the ARGO pictures, I do decode with ARGO the WAV file that has been recorded at the same time. Then I do know the exact frequency of the desired signal. And then I do convert the desired signal with this program to make it audible.

Something about the software
The conversion of the QRSS signal in the audio band of 1500 Hz to 1600 Hz to approximately 45 Hz is done by means of a low frequent SSB receiver. It works in accordance with the Weaver method.



The Weaver SSB receiver does use the phase method to suppress 1 side band. The first oscillator F1 is tuned to the signal in the audio band of 1500 Hz to 1600 Hz. The second oscillator is tuned to the new frequency of 45 Hz.

```
L = len(WAVsignal1)
while n < L:
    I = float(WAVsignal1[n]) * math.sin(H1)      # The first I mixer of the Weaver SSB receiver
    Q = float(WAVsignal1[n]) * math.cos(H1)      # The first Q mixer of the Weaver SSB receiver
    H1 = H1 + ST1
    while H1 > TWOPI:
        H1 = H1 - TWOPI

    # The IIR routine and coefficients from http://www-users.cs.york.ac.uk/~fisher/mkfilter/trad.html
    xvi0 = xvi1
    xvi1 = xvi2
    xvi2 = xvi3
    xvi3 = xvi4
    xvi4 = I / GAIN
    yvi0 = yvi1
    yvi1 = yvi2
    yvi2 = yvi3
    yvi3 = yvi4
    yvi4 = (xvi0 + xvi4) + 4 * (xvi1 + xvi3) + 6 * xvi2 + (C1 * yvi0) + (C2 * yvi1) + (C3 * yvi2) + (C4 * yvi3)
    vi = yvi4

    xvq0 = xvq1
    xvq1 = xvq2
    xvq2 = xvq3
    xvq3 = xvq4
    xvq4 = Q / GAIN
    yvq0 = yvq1
    yvq1 = yvq2
    yvq2 = yvq3
    yvq3 = yvq4
    yvq4 = (xvq0 + xvq4) + 4 * (xvq1 + xvq3) + 6 * xvq2 + (C1 * yvq0) + (C2 * yvq1) + (C3 * yvq2) + (C4 * yvq3)
    vq = yvq4

    v = vi * math.sin(H2) + vq * math.cos(H2)   # The second mixer and adder in the Weaver SSB receiver
    H2 = H2 + ST2

    while H2 > TWOPI:
        H2 = H2 - TWOPI

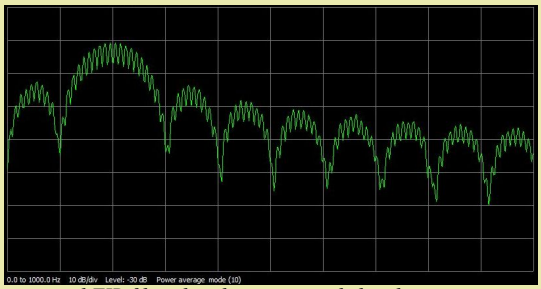
    WAVsignal1[n] = int (v)

    n = n + 1
```

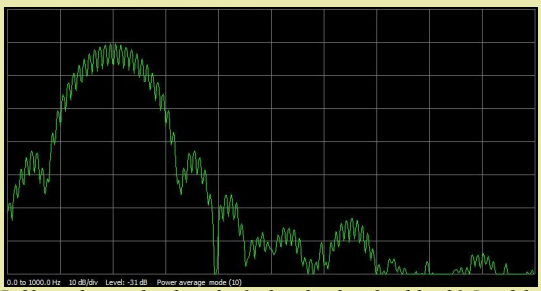
And this is how you make such a receiver in software! The first mixer, two IIR filters as low pass filter and the second mixer plus adder.

There are two solutions for the digital filters, a FIR filter and a IIR filter. a FIR filter is very stable but does need a shift register with very many taps. For a 10 Hz bandfilter even 600. And for every sample, all those 600 taps have to be multiplied with a certan factor and added. The multiplication factors do determine the shape of the filter. Very much calculations, 600 calculations per sample. But there is an exception, the so called Moving Average Filter. Here all multiplication factors of all the taps do have the value 1. Only the first and the last tap have to be added resp. substracted. And ony 2 calculations are required, regardless the length of the shift register or the number of taps. Such a filter is used here. Of course, the shape is not so good, there are many side bands. But here, three FIR filter are placed after each other, the 2nd with a bandwidth of 1.5x of the first and the third again with a bandwidth of 1.5x of the second filter. In that way, the first side bands of a FIR filter are suppressed by the zeroes of the subsequent FIR filter.

The pictures here below were made with a multi carrier WAV audio signal. It consists of many small signals, separated 10 Hz in frequency from each other. That is why you do not see a constant curve, but many small signals, separated 10 Hz from each other.

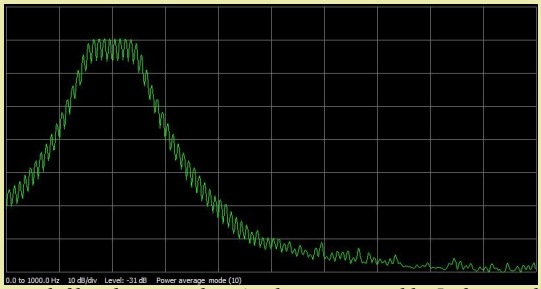


Although the original FIR filter does have many side bands, it was quite good useable.
But the side band suppression can be much better. The conversion takes some more time then.

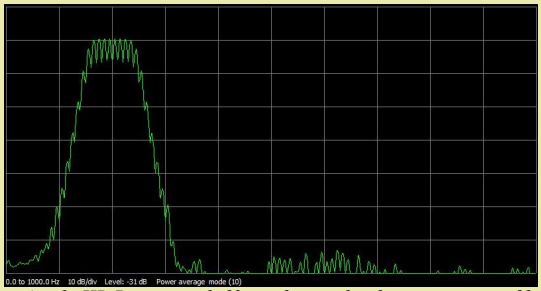


Three FIR filter after each other, the 2nd with a bandwidth of 1.5x of the first one and the third one with a bandwidth of 1.5x of the second. In that way, the first side bands of a FIR filter are suppressed by the zeroes of the subsequent FIR filter.

But you can also use an IIR filter. The advantage of an IIR filter is that it needs a much shorter shift register, so much less taps. That is because a part of the output signal is fed to the input. But more than 4 poles seems to be not so good, then the filter does become too instable. Here you can switch two 4 pole filters after each other for a better slope of the filter. A better solution seems to be to place a number of 2 pole IIR filters after each other. But I do not have enough knowledge to do that.



An IIR Butterworth filter, but more than 4 poles is not possible. In fact you have to place more 2 pole IIR filters after eacht other due to the extreme gains that are otherwise required.



Two 4 pole IIR Butterworth filter after each other, a very nice filter!

SOFTWARE

Before you are using this program, you have to install Python. That is very simple. But read first something about Python by clicking the following link:

WHAT IS PYTHON AND HOW DO YOU INSTALL PYTHON

As the source code of Python is written in ASCII, it is very simple to modify the program to you own requirements. Think for example about the size of the screen, the colors etc.

Required Python version:

- Python version 2.6 or 2.7

Required external modules (site-packages for the correct Python version!):

- pyaudio

Download here the Python program by clicking the link here below:

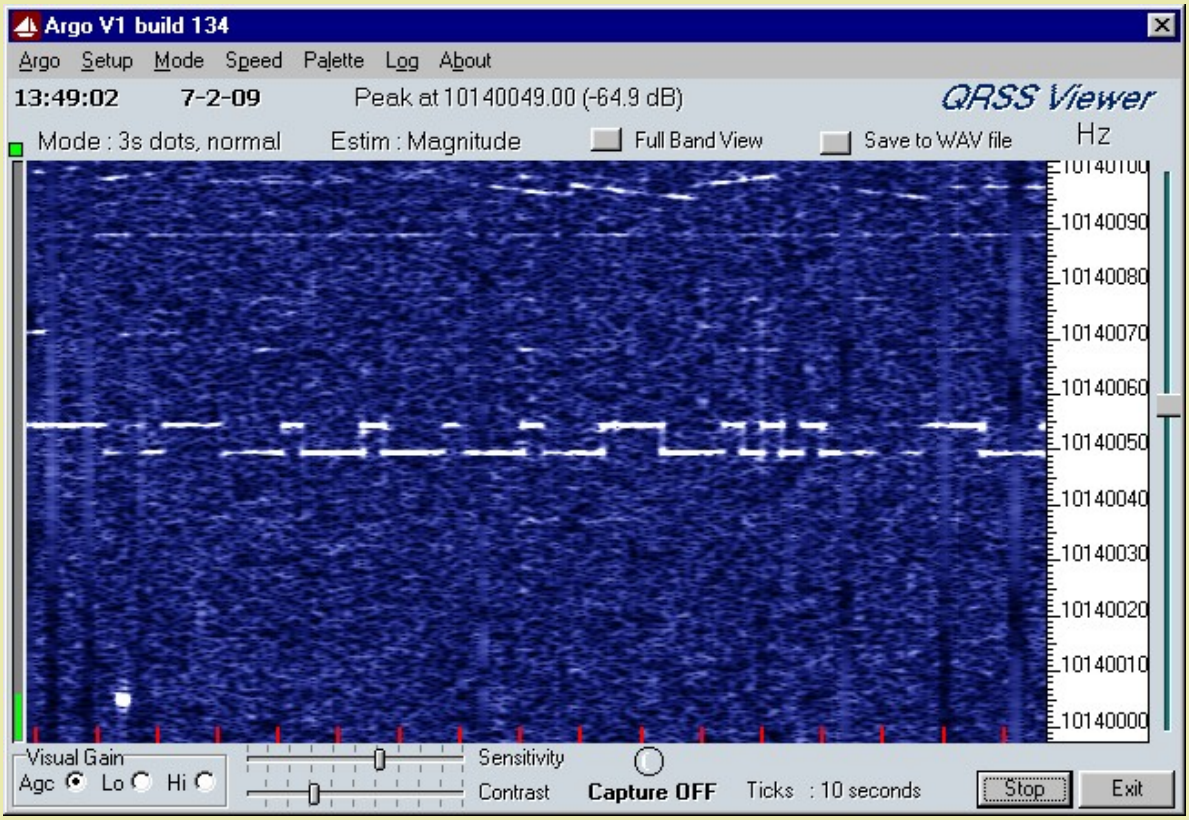
- QRSSaudioSSB-v01.py (24-07-2012)

BACK TO INDEX PA2OHH

SIMPLE 30 METER RECEIVER FOR LOW POWER QRSS BEACONS AND PSK31

(2009)

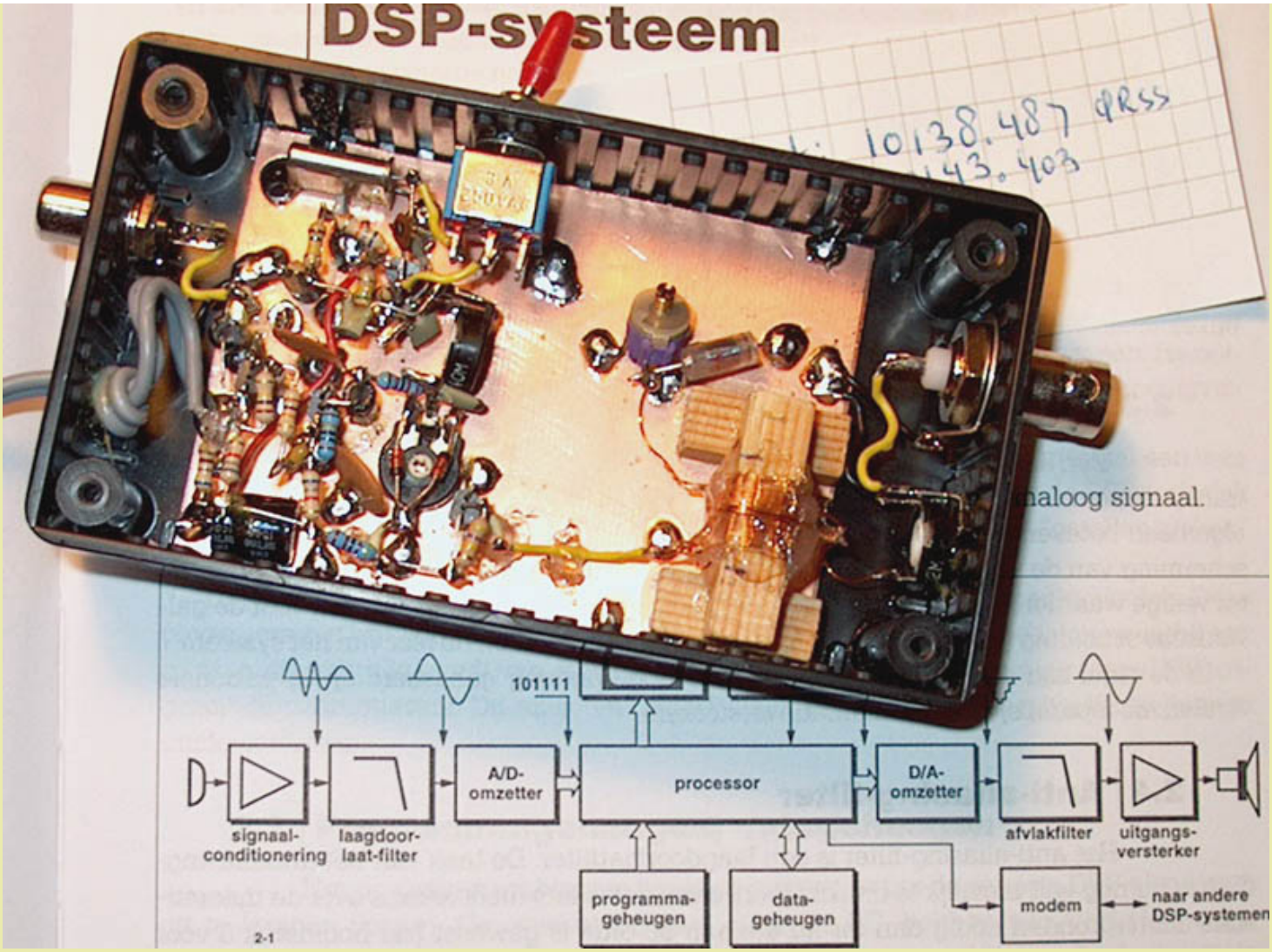
KLIK HIER VOOR DE NEDERLANDSE VERSIE



I0/N2CQR, a 20 milliwatt beacon in Rome!
Absolutely inaudible, but perfectly visible!

Reception of very low QRSS beacon transmitters

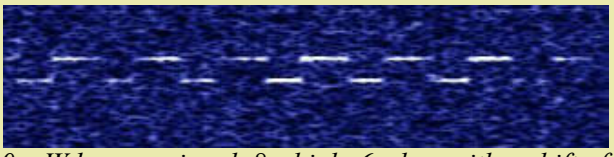
There is a group enthusiastic radio amateurs that is doing experiments with very low powers. That is possible by using a low CW speed. QRS mean reduce your CW speed. With that extra S of QRSS they want to indicate that it is really a very low CW speed. A point lasts 3 or 10 seconds. Most of the activities take place in a band of only 100 Hz, namely 10140,0 to 10140,1 kHz in the 30 meters amateur band. This band is only half as wide as a narrow CW filter of 200 Hz and just wide enough for 1 CW signal. But it is wide enough for 20 QRSS beacon transmitters! Of course our ear is entirely unsuitable to separate all those signals in that 100 Hz band from each other and from the noise. But our eyes can do that! On the monitor screen of the PC, you can see all those signals, detected by special software. The audio output of the receiver is connected to the sound card of the PC. With a special software program, you can make bandwidths of 0.3 Hz or even less.



The simple receiver for 30 meters QRSS beacons and PSK31. I wanted to receive the 10 milliwatt beacon transmitter with it during my holidays!

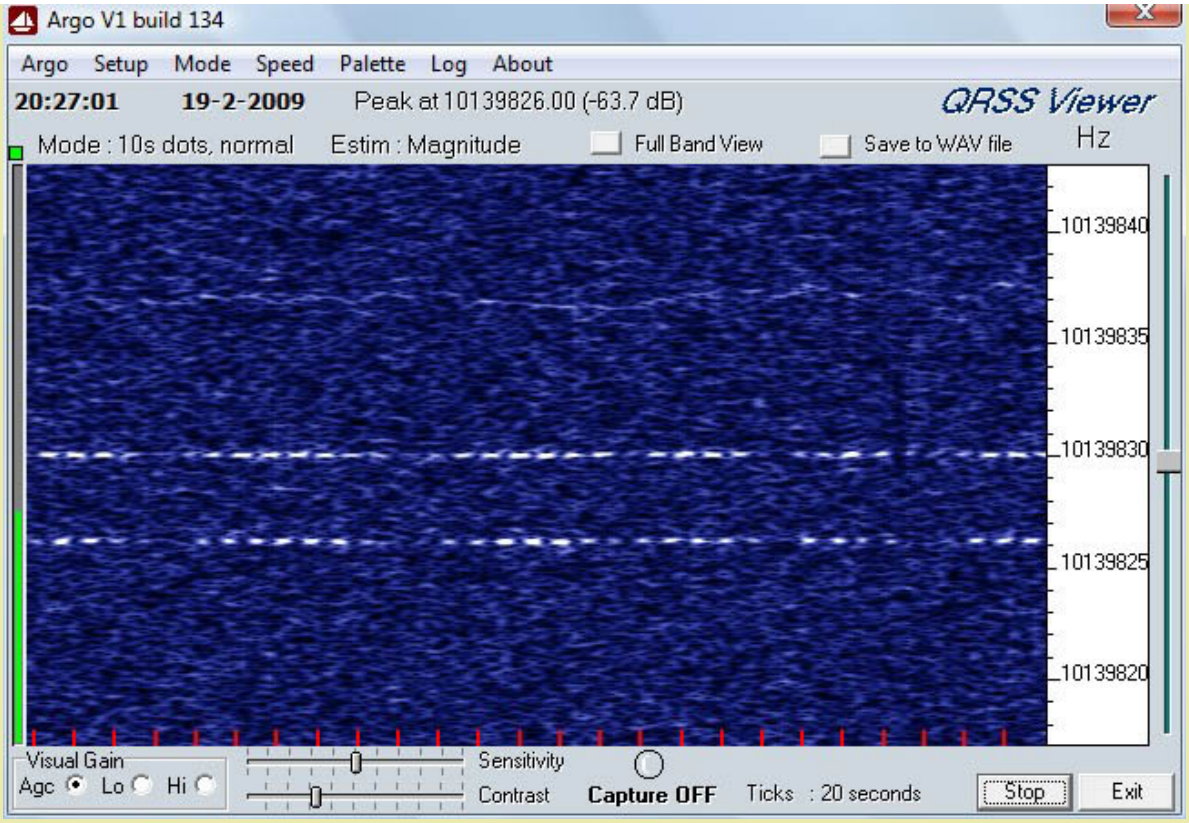
Experiments with the 10 milliwatt QRSS beacon transmitter

I wanted to try to build a 10 milliwatt beacon transmitter and to receive it during my holidays in Spain. It seems impossible and in the past when we could only receive CW by ear, that was indeed impossible. Low QRP power of 1 watt is already 100x lower than the 100 watt that a normal amateur is using. And those 10 milliwatt are again a factor 100x lower, so 10000x lower than the usual 100 watt! Compared to this power, my small 1 watt QRP transceiver is a high power QRO transmitter! The portable shortwave receiver was not stable enough. Also the frequency reading was too inaccurate, an accuracy of 30 Hz is required to find the beacon transmitter. So a simple, but stable receiver with a crystal oscillator was made. I took this receiver with me during holiday to Spain. The 10 milliwatt beacon would be switched on when requested by telephone by a volunteer.



The 10 mW beacon signal, 8 s high, 6 s low with a shift of 4 Hz. It could be received at a distance of 1650 km!

As you can see here above and below, it was possible to receive the 10 milliwatt beacon at a distance of 1650 kilometres with a very simple receiver! Incredibly! The vertical short transmitting antenna is not so good, the central heating is used as a ground. And that bad antenna is behind the roof with insulation plates with metal foil. And in Spain, a mountain was located in the direction of the Netherlands. However, after a 2100 kilometres long drive of 2 days we were still within the range of the 10 milliwatt beacon transmitter!



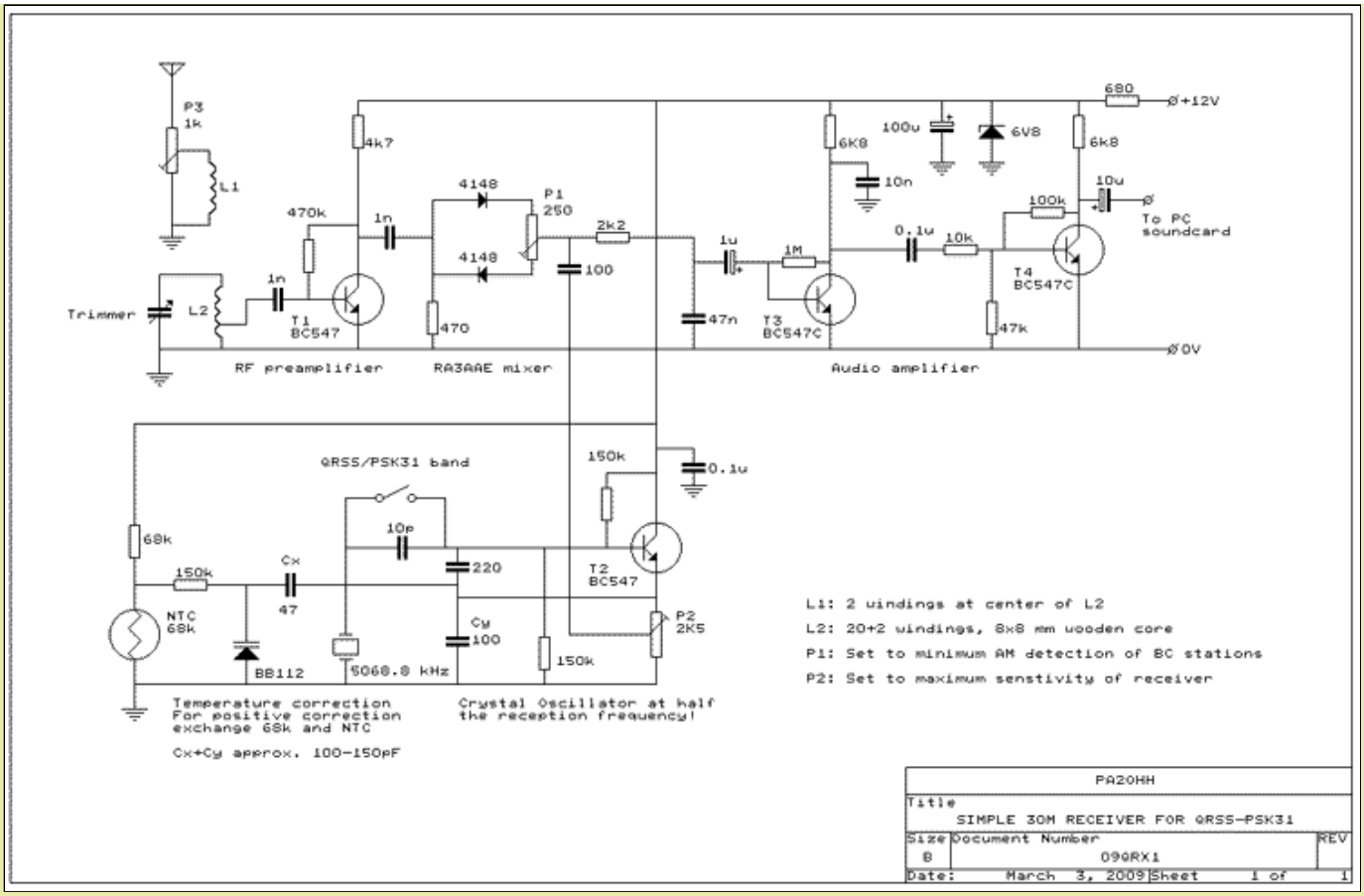
Here a recording during 8 minutes with a smaller bandwidth.
Absolutely inaudible, but those 10 milliwatts were often visible!

Comparison of QRSS with CW

A test was done to compare QRSS with CW decoded by ear. The signal of the RF signal generator was adjusted so that slowly transmitted CW could be received by ear. The QRSS signal with 3 second dot length, decoded with the program ARGO, was reduced so that it was still perfectly visible. The difference was more than 20 dB (100x). Others also have found this value. So the 10 milliwatt QRSS signal of the beacon transmitter can be compared with a 1 watt CW signal. But in practice the difference is often larger. Those 20 dB apply to CW signals in the noise. In practice you will have more interference from CW signals close to your frequency than from the noise. You do not have that problem with QRSS. Due to the small bandwidth, other signals close to your frequency are completely suppressed.

Explanation of the diagram of the receiver

Very good available are crystals of 5068,8 kHz or close to half the reception frequency of 10140 kHz. For this reason, a receiver was made based on the design of the simple receiver (somewhere else on this site). The local oscillator of this receiver operates on half the reception frequency. And it is a receiver without difficult components and with reasonable performances. I also heard somewhere that crystals with a frequency of 5 MHz are the most temperature stable ones. That is important. When you work with bandwidths of 0.3 Hz, even a crystal oscillator is very unstable. Blowing in the receiver for a moment and it is unusable during a long time because of the frequency drift!



Circuit diagram
big diagram

RF preamplifier
T1 is an ordinary LF transistor. The tuned circuit is adjusted by ear for maximum sensitivity. L2 is 20 windings on a wooden core of 8x8 mm with a tap at 2 windings to the base of T1. The antenna winding L1 of 2 windings is wound over the center of L2. The (adjustable)potentiometer P3 of 1k is the RF control. You can use it to avoid overloading of the receiver in the evening by strong broadcast stations. You can use an adjustable potentiometer as you will not adjust it so often, only once or twice per day.

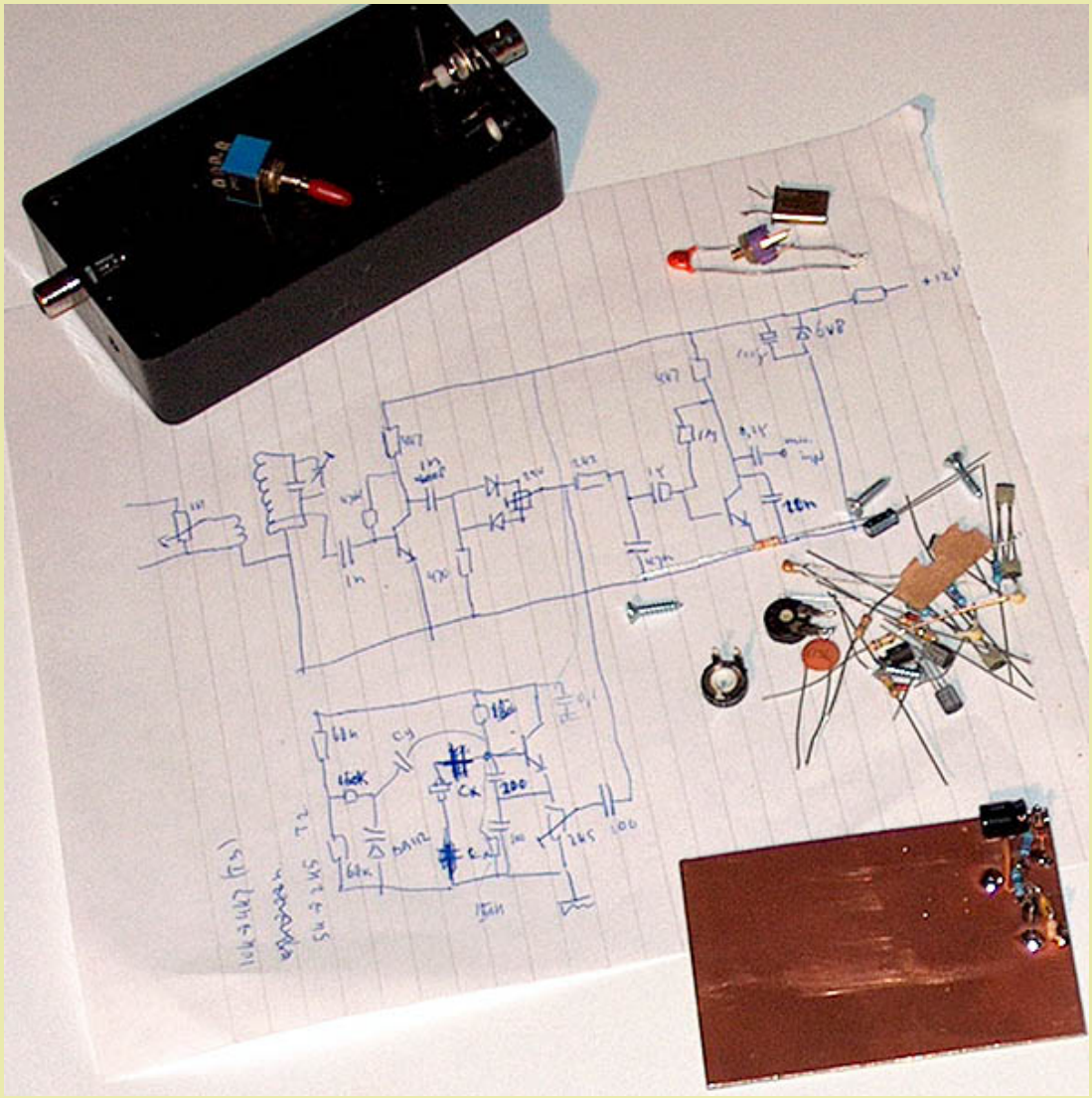
RA3AAE mixer
One of the diodes conducts during the positive half period of the sine of the crystal oscillator, the other diode during the negative half period of the sine. But due to the voltage drop of approximately 0.7 V, the diodes will only conduct during the positive top and the negative top of the sine and not near the zero crossings of the sine wave of the crystal oscillator. So they do behave like a switch that switches 2x on/off during one sine period. That is why the crystal oscillator has to work on half the reception frequency! And that is the frequency of the cheap, easily obtainable 5068.8 kHz crystal. The level of the oscillator is very important and can be adjusted with P2 by ear.
With P1 and a correct adjustment of it by ear, the sensitivity for strong AM signals can be reduced considerably.

VXO
The crystal oscillator works on 5068.8 kHz, just beside half the reception frequency. The exact value is not important, it is measured during the calibration and corrected in the software. You can receive the QRSS becons between 10140.0 - 10140.1 kHz. The frequency of the crystal oscillator should be so, that the beacon band is somewhere within the audio range of 1 to 2 kHz. By means of a serial capacitor, the frequency can be increased so that you also can receive PSK31 stations above 10142 kHz.

Temperature stabilisation
Between 10 C and 30 C, the frequency drift was approximately 20 Hz. Already much better than the 70 Hz of the beacon transmitter. It seems indeed that 5 MHz crystals are more temperature stable. Often an oven is used to stabilize the temperature of the crystal. That was not possible here because of the high supply current of an oven. I wanted to use batteries to supply the receiver. But with a NTC resistor and a varicap a temperature correction was made and the drift reduced to less than 5 Hz between 10 C and 30 C. For an upwards frequency correction, the NTC has to be connected as in the diagram. For a downwards correction, exchange the NTC and 68k resistor. Of course you can also take a NTC resistor

with another value. Exchange the 68k resistor then for a resistor with the same value as the NTC. Increasing Cx and reducing Cy increases the correction, reducing Cx and increasing Cy reduces the correction. Finding the correct value is a question of trying out while cooling down and warming up the receiver with various values of Cx and Cy.

Low frequency amplifier
One transistor was not enough for the weak QRSS signals. That is why an extra transistor T4 was added. The output is low impedant due to the strong feedback via the 10k / 100k resistive divider from the collector. A cable that is connected to a low impedant source is less sensitive for interferences. And by adding extra gain, the level on the connection cable with the soundcard is increased and because of that even less sensitive for interferences (hum etc.). Therefore, it is possible to use a long, unscreened flat thin loudspeaker cable for the connection between the receiver and the soundcard input of the PC. So it is not necessary to place the PC close to the receiver and the flat cable fits easily under a door.



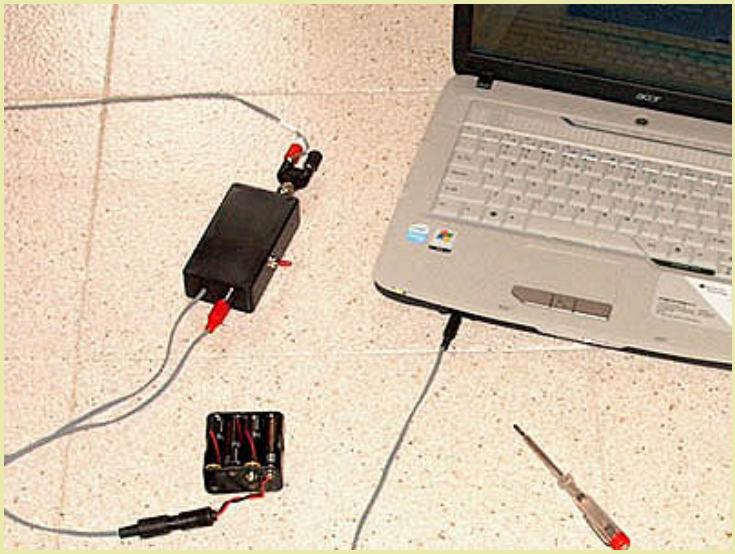
The circuit is mounted in a plastic housing on an unetched piece of PCB.

Construction
The circuit is mounted in a plastic housing on an unetched piece of PCB. That is simple, quick and it is easy to change the circuit. That last advantage is very important, the final design was modified considerably. That is not possible with a printed circuit design! Due to the supply with batteries, the receiver can be used independently of the mains supply with a laptop with accu.

Software
On the internet you can find various suitable software programs. Just search for QRSS and you will find all kinds of software and many very interesting information. I use ARGO of Alberto, I2PHD and Vittorio, IK2CZL. For uploading of the ARGO screencaptures I use Argo Upload by Rik Strobbe (ON7YD). Then it is possible to see via internet what the receiver at home does receive at that moment.

Calibration

For the program ARGO, two calibrations have to be done. Firstly the accuracy of the soundcard. You can do that by touching the input of the soundcard with your finger and to measure the 11th harmonic of the mains (550 Hz or 660 Hz if the mains frequency in your country is 60 Hz). My soundcard had a deviation of 11 Hz! Or the "measured frequency" was 550 Hz and the "displayed frequency" was 561 Hz. However, the laptop had a deviation of 0 Hz!
After the calibration of the soundcard, the local oscillator frequency has to be entered in the ARGO program. You cannot measure it, connection of a frequency counter will cause a shift in the crystal oscillator frequency. So connect a signal with a known frequency (for example 10140 kHz) to the receiver and adjust the offset value in the ARGO program so that it displays the correct frequency. I do use a frequency counter with simple frequency standard to measure the frequency of the known signal. For my receiver, the offset is 10138487 Hz, so the crystal oscillator frequency is 5069.243 kHz. And the QRSS beacon band of 10140.0 to 10140.1 kHz is in the audio range 1513 to 1613 Hz.



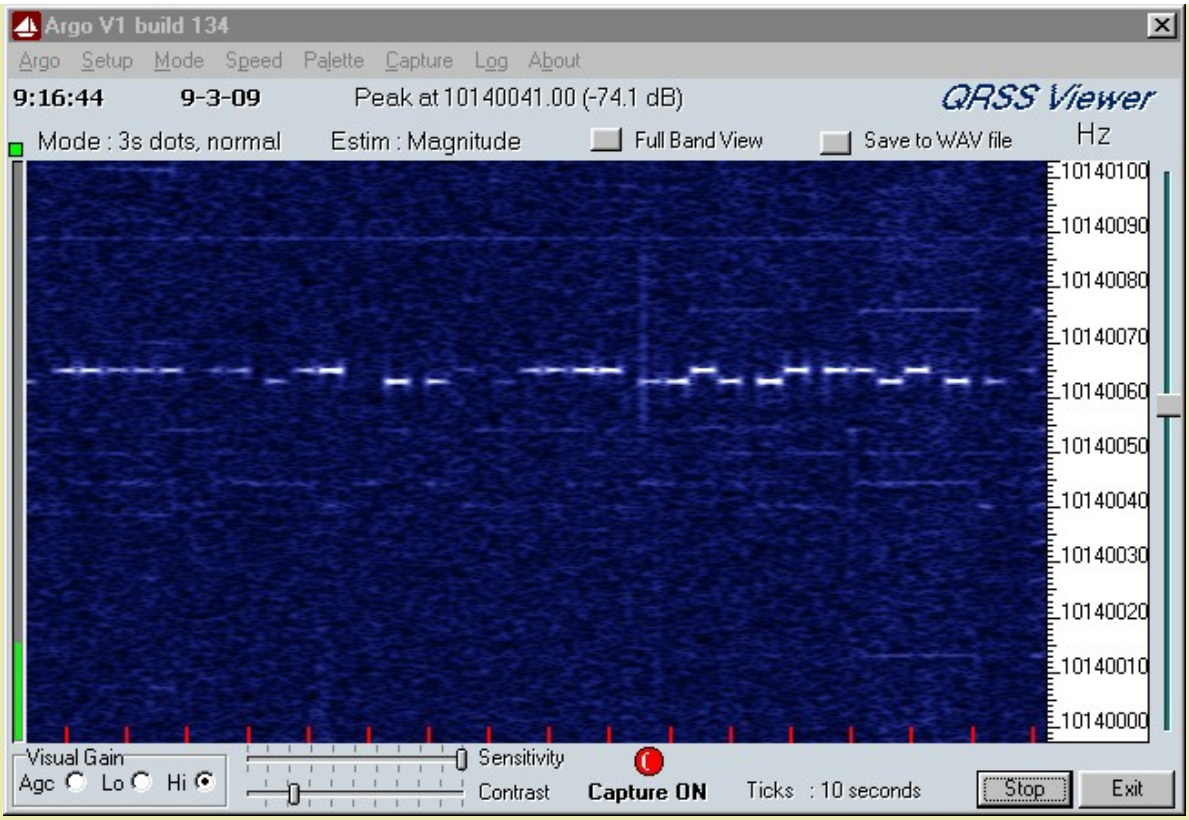
The complete station: receiver, batteries, laptop and a screwdriver to adjust the RF attenuator.



The antenna was at a height of 2 to 3 meters behind the house in the trees.
The flat, thin antenna cable fitted through a small hole near a window.

Description of the mobile reception station

The receiver, the antenna and the connection cable with the PC and the batteries were all stored in the laptop bag. The antenna was made from a piece of flat thin loudspeaker cable of 15 meters. The final 5 meters was split into a dipole antenna of 2x5 meters. The remaining 10 meters is the antenna cable to the receiver. The outer ends are mounted in a banana-BNC coupling adaptor. The flat thin cable fits easily through a hole, that is often a problem with coax and a coax plug.
The cable between the receiver and laptop is 8 meters long, it is the same flat cable as is used for the antenna That is quite long. But then it is possible to place the receiver in a bedroom and the laptop in the kitchen or living room. It was very important to use the internal accu of the laptop. Reception of QRSS signals was not possible when the charger was used due to its radio interference.



EA1FAQ with 10 milliwatts, received in The Netherlands. From Spain to The Netherands is also possible! Dashes are a dot with a high shift, a "dot" is a dot with a low shift.

Results

Various other low power QRSS stations have been received. They were not audible, not even with a very good receiver. PSK31 reception is good because of the excellent frequency stability. But this were only the first experiments. There are already amateurs who have been received at the other side of the Atlantic Ocean with only 1 milliwatt! And I thought that 1 watt was already extremely low power...

For the next time, the power of the beacon transmitter will be reduced from 10 mW to 1 mW and the transmitting antenna will be improved. And the unwanted sideband has to be suppressed. That gives already an improvement of 3 dB (2x)!

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10 MILLIWATT BEACON TRANSMITTER FOR 30 METER KEYED BY AN AUDIO PLAYER

(2011)

KLIK HIER VOOR DE NEDERLANDSE VERSIE

Experiments with very low power QRSS beacon transmitters

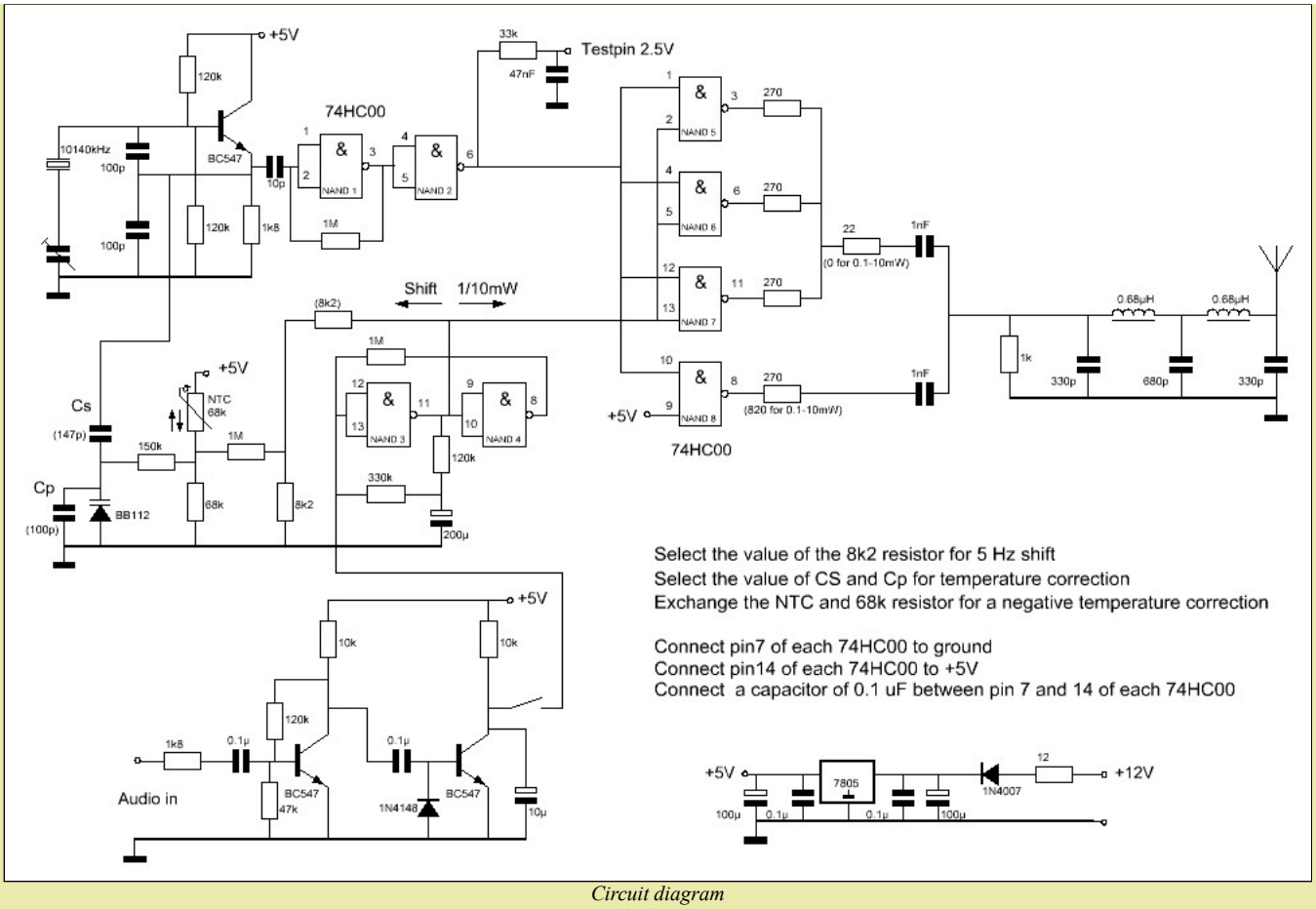
There is a group enthusiastic radio amateurs that is doing experiments with very low powers. That is possible by using a low CW speed (QRSS speed). Most of the activities can be found in a band of only 100 Hz, namely 10140.0 to 10140.1 kHz in the 30 meters amateur band. Signals are decoded with a special software program. My beacon transmitter could only be modulated with a square wave with a frequency shift of 4 to 5 Hz. But for the serious work, in morse code the call, QTH locator or transmit power had to be transmitted. But how can that keying with morse code be realized?



The beacon transmitter is keyed by a WAV file that is played by an audio player (MP3/WAV player). Here I do use a mobile phone as an audio player. But you can use all kinds of other audio MP3/WAV players of course.

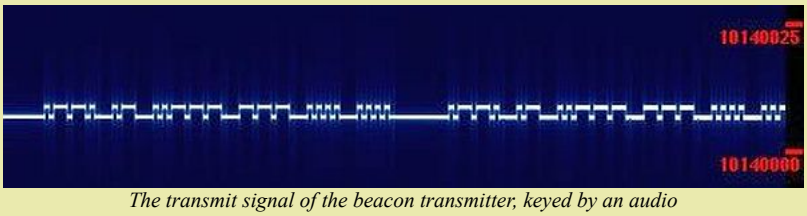
Keying with an audio player

For keyng the beacon transmitter with morse code, I had already a solution with a light dependend resistor (LDR) in front of a PC monitor. On the screen was a black and white flashing square in the rythm of the morse code. But then, the PC had to be switched on all the time, 100 watt power to key a 10 milliwatt transmitter, what a waiste of energy! There had to be a better solution. For example an audio player! You can set the audio player so that it repeats an audio file all the time. For making the audio WAV file, a computer program in Python was written. My call in morse code with a dot length of 3 seconds and also an audio file with a dot length of 6 seconds. When you want to change the dot length, you do not have to re-program a micro controller, but you simply select another audio file on the audio player! And the beacon transmitter was modified so that it could be keyed by the incoming audio signal. A detector makes zeroes and ones of the morse code tones. And... my mobile phone can also pay WAV files! I do not use that telephone to make telephone calls, I do not have friends. When you do use a telephone as audio player, take out the SIM card, otherwise incoming telephone calls can disturb the modulation. But you can also use all kinds of other WAV/MP3 players of course.



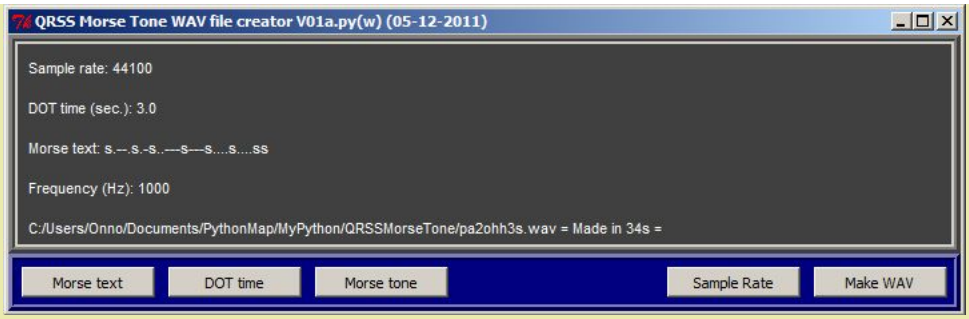
Circuit diagram
big diagram

Description of the circuit diagram of the transmitter
A crystal oscillator with a BC547 transistor is buffered by NAND1 and NAND2 and amplified by NAND5 to 8. The circuit with NAND3 and NAND4 is a square wave oscillator. When the switch is opened, the transmitter is frequency modulated by this square wave. But also in amplitude. During the positive half of the square wave, NAND5 to 8 are all switched on and the transmit power is 10 mW. During the negative half of the square wave, only NAND8 is active and the transmit power is only 1 mW (or 0.1 mW, depending on the used resistor values). When the switch is closed the transmitter is keyed by the audio signal of the audio player. The left BC547 does amplify this signal, the right BC547 with diode 1N4148 is the detector that makes zeroes and ones out of it. Set the volume control quite high. The capacitor of 10 uF does suppress the audio and other interferences.
During the transmission of a dot or dash, the transmit power is 10 milliwatt. During spaces, the transmit power is 1 milliwatt (or 0.1 mW, depending on the used resistor values) and the transmit frequency is lowered with 4 to 5 Hz. But for the current experiments, the beacon does transmit both shifts with 10 mW. The NAND's are all connected to +5V instead of to the output of NAND3.



The transmit signal of the beacon transmitter, keyed by an audio player (MP3/WAV player). Here, the power of both shifts is 10 milliwatt, but you can also transmit with a lower power during the lower shift.

Temperature stabilization
The frequency has to be very stable. It is quite difficult to adjust the beacon transmitter on a frequency of 10140.0 tot 10140.1 kHz and to avoid drift due to temperature changes. A temperature correction circuit was made with a NTC resistor and a varicap. The drift could be reduced considerably. For a positive frequency drift correction, you have to connect the NTC in accordance with the diagram. For a negative correction, the NTC resistor and 68k resistor have to be exchanged. Of course you can also take a NTC resistor with a different value. Exchange the 68k resistor then for one with the same value as the NTC. Increasing of Cs and reducing Cp increases the correction, reduction of Cs and and increasing of Cp does reduce the correction. Finding the correct value is a question of trying out while cooling down and warming up the transmitter with various values of Cs and Cp. Between 5 and 35 °C, the temperature drift is only 4 Hz.

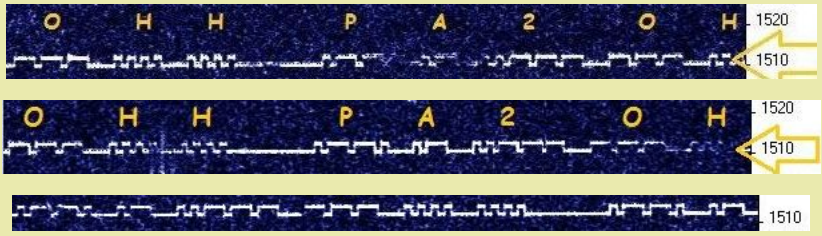


The Python program to make the WAV audio file.

How to make the WAV file
For making the WAV file with the morse code, many programs can be found on the internet. I did use an in Python written program.
See for a description of this program: 11qrssmo.htm

Results, both shifts 10 mW (click on the pictures to see the originals)
It works! The beacon transmitter is transmitting during many week now with the audio player without interruptions or any problems. Boths shifts are transmitted with 10 mW.

Reports
I received via e-mail beacon reports from YO7CKQ (Romania). Many thanks!



The 10 mW beacon signal received by YO7CKQ - (KN15pa).

And also via e-mail a report from Johan, PA0TAB, who lives approximately 20 km from my QTH.

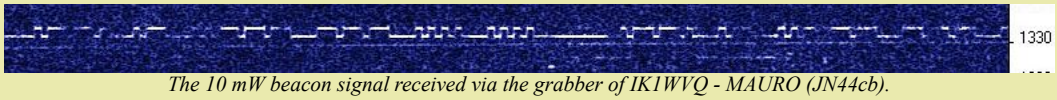


The 10 mW beacon signal received by Johan, PA0TAB (20 km from my QTH).
Grabber of Johan, PA0TAB: http://pa0tab.nl/grabber.html

Grabbers
But there are other possibilities to collect reception reports. There are amateurs who have their receivers coupled to internet. The reception results are continuously refreshed. You can see these results on internet (Search via Google for "QRSS grabbers"). The results here below were obtained via these QRSS grabbers.



The 10 mW beacon signal received via the grabber of G4CDY - TERRY (IO91wh).



The 10 mW beacon signal received via the grabber of IK1WVQ - MAURO (JN44cb).

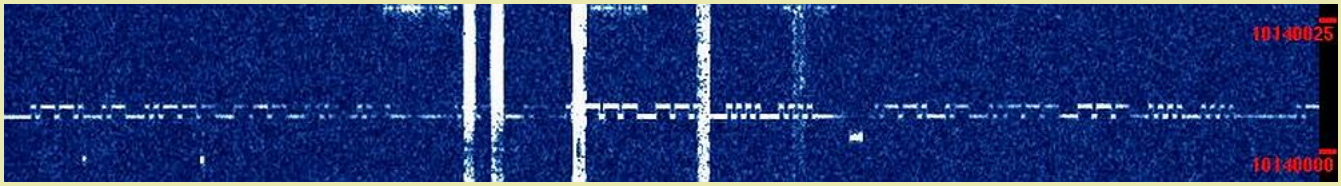


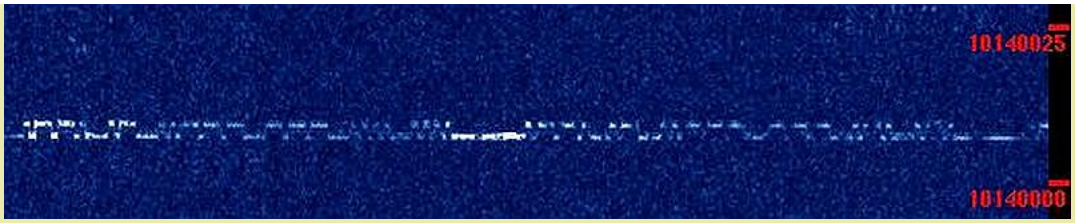
The 10 mW beacon signal received via the grabber of PA1GSJ/DL1GSJ - JOACHIM (JO22da).

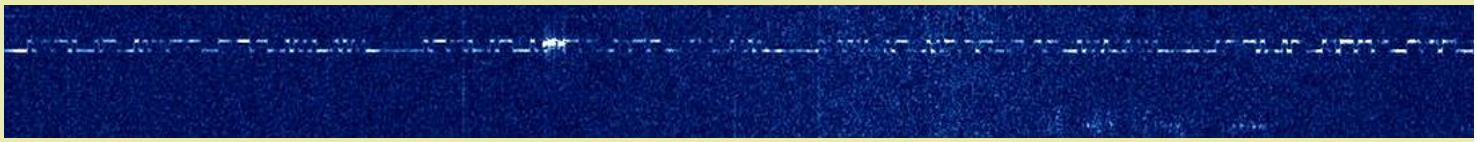


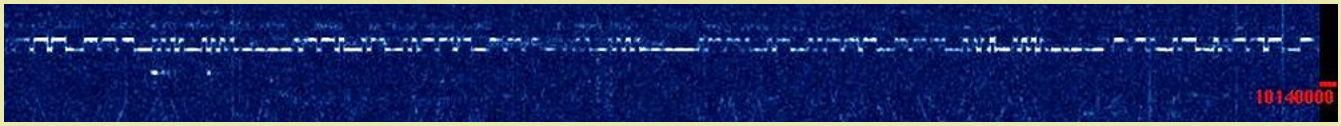
The 10 mW beacon signal received via the grabber of SA6BSS (JO68sc).

Holidays
And you can go travelling to a location! Here some reception reports of the beacon during holidays in Spain!

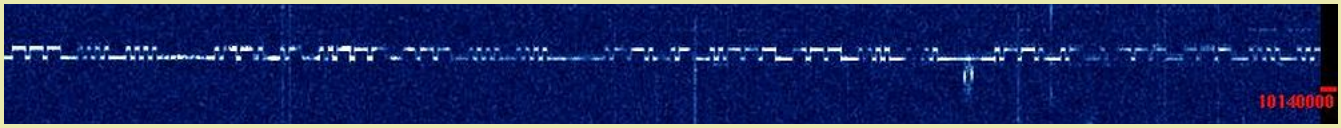


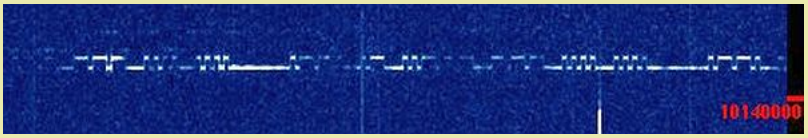










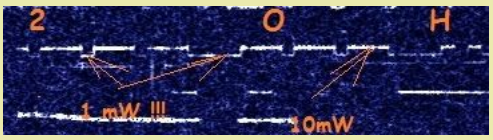


The 10 mW beacon signal received during holidays in Spain (IM98wu).



The 10 mW beacon signal received during holidays in Spain (IM98wu).
Here 12 pictures mean stacked with the program RotAndStack.
(http://www.gdargaud.net/Hack/RotAndStack.html)

Results, low shift 1mW, high shift 10 mW (click on the pictures to see the originals)
And here two results with the low shift of 1 mW and the high shift of 10 mW.



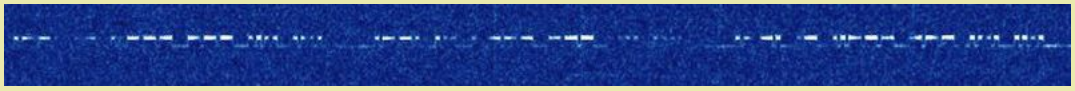


The 1 mW low shift - 10 mW high shift beacon signal received by YO7CKQ - (KN15pa).



The 1 mW low shift - 10 mW high shift beacon signal received by the grabber of IK1WVQ - MAURO (JN44cb).

And... You can take the QRSS beacon receiver with you during holidays to try to receive the beacons signal with 1 mW low shift - 10 mW high shift!



The 1 mW low shift - 10 mW high shift beacon signal received during holidays in Spain (IM98wu).



The 1 mW low shift - 10 mW high shift beacon signal received during holidays in Spain (IM98wu).



The 1 mW low shift - 10 mW high shift beacon signal received during holidays in Spain (IM98wu).
Here 9 pictures sort stacked with the program RotAndStack.
(http://www.gdargaud.net/Hack/RotAndStack.html)

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REMOTE CONTROL OF MY QRSS BEACON TRANSMITTER

(2017)

KLIK HIER VOOR DE NEDERLANDSE VERSIE



A weekend far from home on a deserted place in the snow? You do not have to switch off your MEPT, you can control your MEPT with your smartphone!

Remote control of the QRSS beacon transmitter

It is not allowed to operate your beacon transmitter unmanned, so you have to stay at home! Therefore, such a beacon transmitter is also known as a MEPT, a Manned Experimental Propagation Transmitter. But with simple software, it was possible to control my MEPT remotely with the new smartphone! And that new smartphone does more, it collects data from the grabbers so that you can have a look at the reception results of your MEPT at any time of the day on your new smartphone!

The idea is simple. At the beginning of each broadcast, the old smartphone downloads a confituration file from a FTP site (for example your website or an FTP server on a PC) that controls the MEPT. Is the DOT length zero (less than 200 ms), then the transmission stops. Not everything can be programmed, only the synchronization and DOT time. For example not the call to avoid unwanted errors. The software was written again in the free programming language RFO basic.

Download the RFO basic program by clicking on the link here below:

- 17ftpbesoft.zip



The beacon transmitter is keyed by the audio output of a smartphone.
With some simple software it can be remote controlled!

Adaption of the MEPT software

My MEPT is keyed by the audio output of an old smartphone. The software is written in RFO basic. A detailed description with details about installing RFO basic on the smartphone can be found at the following link:
16rfobenl.htm
The program "qrssFTPtx1.bas" is the new software. Here below a screenshot, you have to modify the lines with the red arrows.

```
REM qrssFTPtx1.bas 2016-11-17 qrss transmitter with FTP remote control

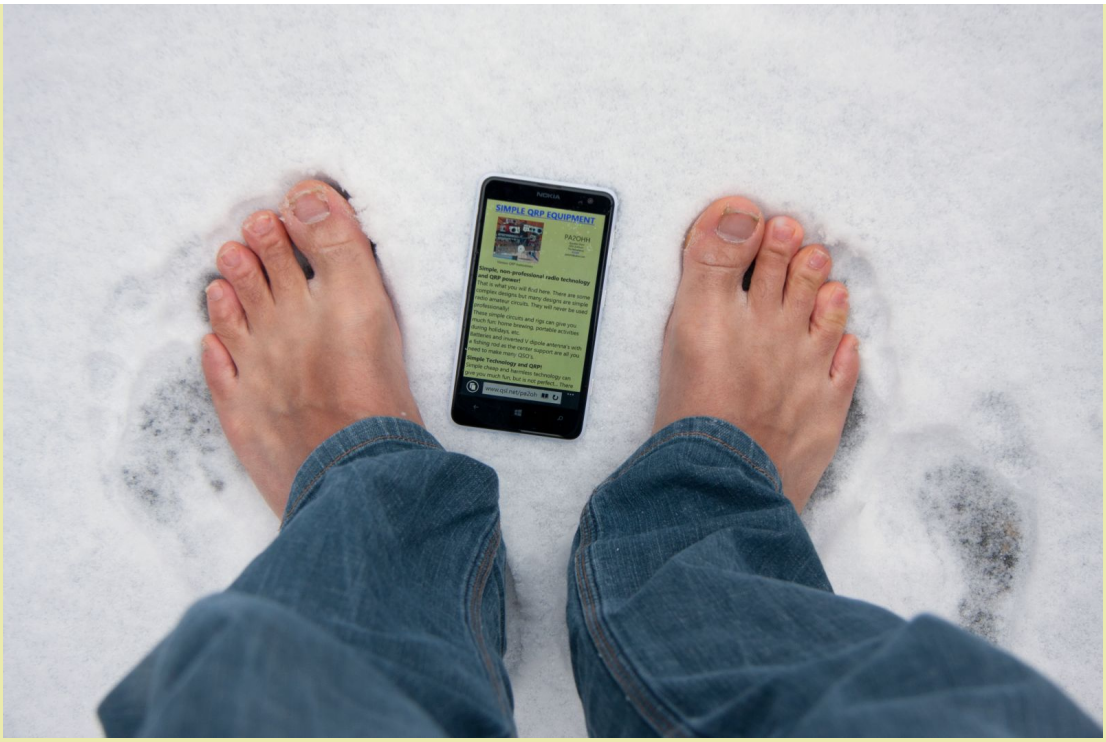
START:
tx$="___.--._._-_..---_---_...._...."
fr=1500     % Tone frequency
vdot=0      % Dot time (ms)
mdelay=0    % Delay (sec)
vstackinterval=10  % (min) 0=non-sync
Wsec=1      % Wait x seconds variable for GOSUB SECWAIT

! Get data from FTP server
CLS
PRINT "Connecting to ftp server..."

FTP.OPEN "ftpsitename", 21, "username", "password"
FTP.GET "/mepts/mept1.txt", "mept1.txt"
FTP.CLOSE
```

The new program "qrssFTPtx1.bas", The lines with the red arrows have to be modified.

Change "tx$" into you own call and en also the FTP settings in that of the FTP site you are using.
As you see, my configuration file "mept1.txt" is located in a separate directory "/mepts/".



You can control your MEPT with the new smartphone!
Even during a walk in the snow!

The software for your new smartphone

For your new smartphone there are the programs "qrssFTPput1-XXX.bas" to activate your MEPT. XXX="off" for off, XXX="on3" for on with 3 seconds DOT time and XXX="on6" for on with 6 seconds DOT time. Width the programa "qrssFTPget1.bas" you can download and read the current configuration file from the FTP server. There is no input screen, the values are fixed in the program. You have to make a separate modified version of the program for each desired configuration with a recognizable name. An input screen was too complex to use. Load and Run the program, you do have 10 seconds to interrupt the program with the backey of your smartphone, then the configuration file will be uploaded.

```
REM qrssFTPput1.bas 2016-11-17 Save "mept1.txt" settings to the FTP server

START:
vdot=6000           % Dot time (ms) 0=off
mdelay=10           % Delay (sec)
vstackinterval=10   % (min) 0=non-sync

CLS

TEXT.OPEN W, FN1, "mept1.txt"
txt$=STR$(vdot)
TEXT.WRITELN FN1, txt$
PRINT txt$
txt$=STR$(mdelay)
TEXT.WRITELN FN1, txt$
PRINT txt$
txt$=STR$(vstackinterval)
TEXT.WRITELN FN1, txt$
PRINT txt$
TEXT.CLOSE FN1

Wsec = 10           % Wait 10 seconds
PRINT "STOP WITH BACKKEY"
GOSUB SECWAIT

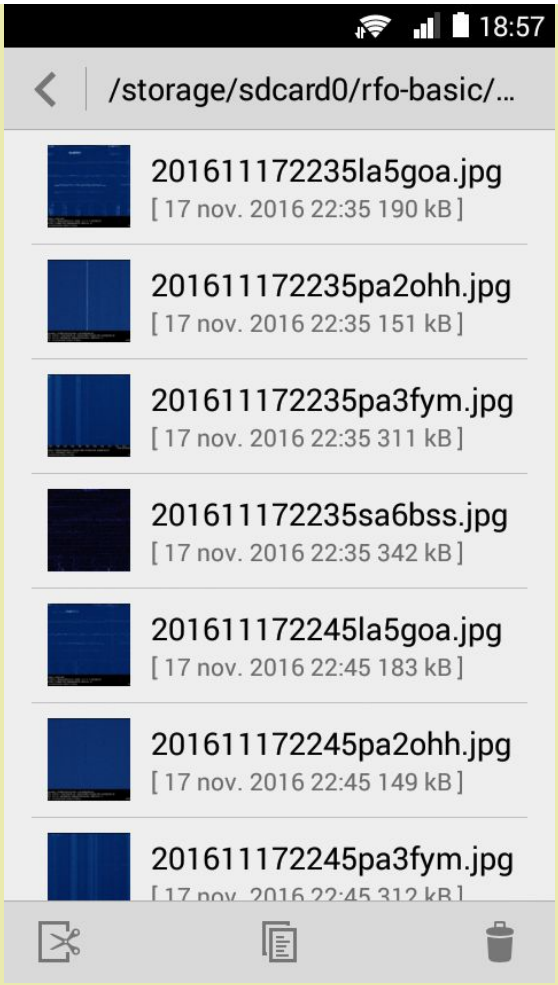
! Save data TO FTP server
PRINT "Connecting to ftp server..."

FTP.OPEN "ftpsitename", 21, "username", "password"
FTP.PUT "mept1.txt","/mepts/mept1.txt"
FTP.CLOSE
```



The program "qrssFTPput1.bas", the lines with the red arrows have to be modified.

"vdot" is the DOT time in milliseconds. Wheb you give it the value "0", the MEPT stops its transmissions. As the accuracy of the timing below 200 ms is not good anymore, the MEPT stops already below that value. So you can also use the program for a normal CW beacon, as long as the DOT time is more than 200 ms.
"mdelay" is a pause in seconds before the transmission starts.
"vstackinterval" is the value for the start of the synchronized transmissions. Normally this value is 10 minutes. If you set this value to "0", then the transmission is not synchronized in time and the next transmissions starts immediately after the previous one.
And of course, the FTP settings have to be the same as in the program "qrssFTPtx1.bas"!



The pictures of the received signals of your MEPT by the grabbers are automatically downloaded on your smartphone.

Download data of grabbers on your smartphone
This is possible with the program "qrssCOLLECT1.bas". The pictures will be downloaded on your smartphone and you can have a look at them later. You can program the time interval for when the downloading has to be done.
Holidays? Without taking radio equipment with you, you can still be busy with Radio!

```
REM qrssCOLLECT1.bas 2016-11-17 Collects grabber pictures

dtime = 10   % Download time 10, 20 or 40 minutes

START:
! Wait till download time
PRINT "Wait for download time" % 5 minutes after download time
DO
 PAUSE 20  % Less CPU load
 TIME vye$,vmo$,vda$,vho$,vmi$,vse$
UNTIL(MOD(VAL(vmi$),dtime))<>5
DO
 PAUSE 20  % Less CPU load
 TIME vye$,vmo$,vda$,vho$,vmi$,vse$
UNTIL(MOD(VAL(vmi$),dtime))=5

CLS

gnr = 1

GLIST:
gname$ = ""
glink$ = ""

IF gnr = 1
 gname$ = "pa2ohh.jpg" % Change to "S"to skip this grabber
 glink$ = "http://www.qsl.net/pa2ohh/lopshot1.jpg"
ENDIF

IF gnr = 2
 gname$ = "la5goa.jpg" % Change to "S"to skip this grabber
 gname$ = "S"          % Changed to "S"to skip this grabber
 glink$ = "http://la5goa.manglet.net/grabber/lopshot1.jpg"
ENDIF

IF gnr = 3
 gname$ = "pa3fvm.jpg" % Change to "S"to skip this grabber
```

The program "qrssCOLLECT1.bas", the lines with the red arrows have to be modified.

"dtime" is the time period between the downloads.
"gname$" is the name of the picture. Watch the right extension, mostly ".jpg". This name is preceded by a date-time stamp. When you change the name into "S" (uppercase!), than this grabber is skipped. The best way to do this is to insert a line as you can see in "IF gnr = 2", otherwise you do not know the name anymore.
"glink$" is the URL of the picture, that is not the URL of the website but of the picture! This URL can be found by clicking with the right mouse key on the picture. You can find the pictures with the explorer in the directory "/rfo-basic/data/".



On a quiet moment you can have a look at the reception results of your MEPT!

BACK TO INDEX PA2OHH

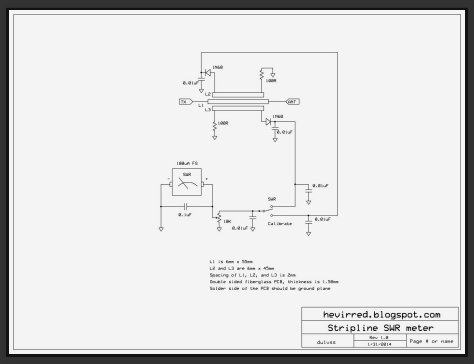
More Next Blog» karlsmirni@gmail.com Dashboard Sign Out

du1vss home brews

All about ham radio. Although some of my projects involved transmitters, rf amplifiers and antennas that operates outside the ham band, these things were solely for educational purpose only and experimentation.

Friday, January 31, 2014

Stripline SWR Meter



Another weekend project that I made is this SWR (Standing Wave Ratio) meter which rf pick-up is a directional coupler fabricated from microstrip. FR4 double sided pcb was chosen with thickness of about 1/16 of an inch on a 2mil copper thickness. Processing the microstrip starts from applying a masking tape on both sides of the PCB and manually drawn the three main important traces on the top side of the PCB. The masking tape on the bottom side was retained so that at the end after etching, it will serve as a ground plane of the microstrip. After etching the board, please verify that the dimension of L1, L2 and L3 are closely followed so that our strip line impedance will be close at 50 ohm, the thickness, width and the material of the PCB has also a direct influence on the impedance.



On my prototype I intentionally separate the directional coupler from the meter unit so that when time comes, I can easily swap between other types of directional coupler design. During the initial test, I found that the prototype respond well to VHF while it requires greater amount of rf energy to produce the same full scale deflection of the 100uA meter at HF. Germanium diode used in this project is not linear specially at different power levels therefore this project is best suited for QRP application only.

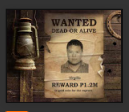
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About Me



hevirred

Ham since 2000.

View my complete profile



The face of the meter can be modified so that a calibrated lines can be drawn using a reference dummy load each with different impedance values. 73 de du1vss.

Posted by hevirred at 4:16 AM

2 comments:



Johnson Diputado January 24, 2017 at 8:06 AM

Hello po DU1VSS, this is DW7DYJ with the handle of Johnson. I am a member of DX7NRD (NORAD7). I am current in the reading phase of my SWR Meter Project when I found your post. I was hoping if you could share with me the dimensions of the microstripline board. Does the size of that board really important or does any do as long as L1 L2 and L3 will all fit in it? Hoping for your positive response. 73 po, will be on QRX. (hear you na lng din po sa DUNET)

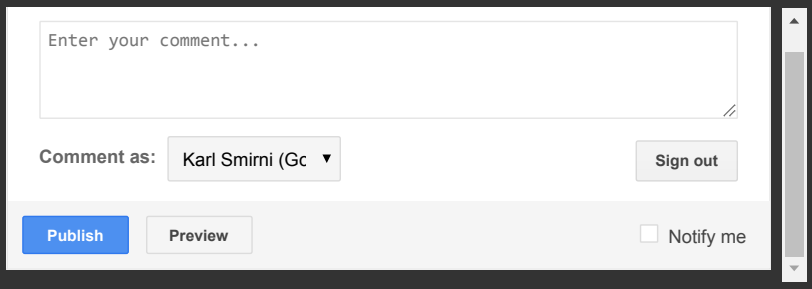
Reply



hevirred January 25, 2017 at 5:19 PM

Hello sir, meron lang po akong correction dun sa dimension ng L1, L2 and L3. dapat po 3mm lang ang width at hindi 6mm.. ang dahilan ay kailangan natin ng 50ohms na impedance sa stripline, yung length ng stripline ay proportional sa sensitivity ng power measurement. yung nasubukan kong 2inches na haba ng board ay sensitive lang ng mga 1W pataas... kung gusto mo ng mas sensitive kailangan mo lang habaan ang stripline like 3 inchess or 5 inches pero dapat ang lapad ng L1, l2 at l3 ay 3mm lang talaga.

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Project 01



MK484 AM RADIO RECEIVER WITH VARICAP TUNING

by TheAstro30

RADIOS are awesome to build; hearing broadcast stations coming out of something you've created for the first time is a really awesome feeling. This is why I have presented this "weekend" construction project; an AM broadcast radio receiver utilising varicap tuning and an MK484 IC. Both the MVAM108 (BB-112) varicap diode and the MK484 IC may be hard to source locally, but these can be found on eBay rather cheaply. And, with the MK484, there would likely be a newer substitute version, so a little research would be prudent.

This circuit is not only just limited to AM broadcast radio (535 to 1605 kHz) and with a little modification to the inductor coils, could achieve tuning below 535 kHz or even higher for shortwave reception. However, with this project, it's designed for standard AM broadcast radio. The over-all build cost shouldn't break the bank and if built in to the plastic enclosure (or similar) I designed it for should only have a price tag of around 50 to 60 dollars; not too expensive.

Circuit Details

Referring to the circuit diagram of fig. 1, RV1 controls the tuning of the receiver. This is achieved by applying a small amount of voltage (isolated by R1) to D1, a varactor (varicap) BB-112 diode. The specs on this diode are it only requires 0 to 8V for a full capacitance range of 22 to 760 pF. The way a varactor diode works is the higher the voltage applied to it is in a reverse-biased configuration, the lower the capacitance will be. This is to do with how the reverse break-down voltage affects the silicon substrate within the diode causing a variation in capacitance and, in essence, we now have a variable capacitor. This new "capacitor" is isolated from the inductor, L2, via varicap D2 (connected in reverse bias with D1) which now, in turn, forms a "tank" or tuned circuit.

Next, L2 is fed in to pin 2 of U1, an MK484 Tuned Radio Frequency (TRF) IC which contains around ten transistors on board providing all the necessary RF and IF amplification and an AM detector. This IC requires only a maximum of 1.8V to operate, so this is biased at pin 3 via R3 to provide the necessary voltage drop. Pin 3 is also fed in to RV2, the "RF Gain" control and this provides feedback (via R2) to L2's tank circuit.

Pin 3 is then blocked for DC via C3 and fed in to RV2, the "Tone" control which uses a basic hi/low pass filter configuration via C5 and C6. The center-tap of RV2 is fed to RV3, the "Volume" control where after passing via C5 (another DC blocking capacitor) is fed in to pin 3 of U1, which is which is an LM386N-1 amplifier IC. This IC is set to a gain of 200 times by capacitor C8, a 10uF 16V electrolytic.

The output is fed to DC blocking capacitor C11 and also has R7 and C10 forming a Zobel network. This provides an output power of around 360mW which is sufficient enough to drive any small loud speaker (say 76 mm from a

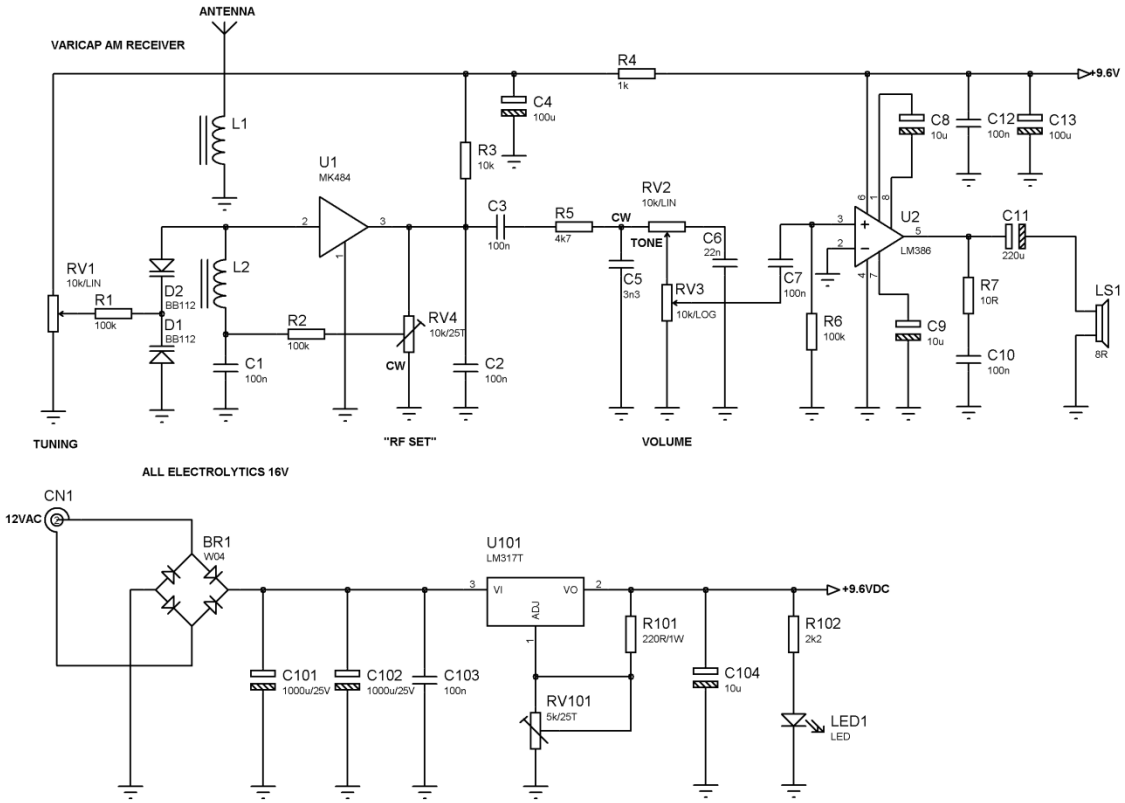


Figure 1 – Complete schematic diagram for the receiver using an MK484 TRF IC (U1) as the heart. The TO-92 style device contains up to ten transistors comprising all of the RF and IF amplification stages as well as an AM detector. The IC itself is capable up to frequencies as high as 3MHz. Amplification to drive a loud speaker to sufficient levels is obtained by use of U2, an LM386N amplifier IC which in turn drives loudspeaker LS1.

clock-radio, for instance) to pretty loud levels.

The power section is based around an LM317T adjustable voltage regulator (U101) so we can precisely adjust the voltage to a given “maximum” voltage. BR1 is a standard W-01 bridge rectifier package which rectifies the incoming 12VAC voltage from CN1 to DC. It is then filtered by C101, 102 and 103. RV101 adjusts the voltage of U101. This will be set later to around 9.6V at the output. The output is further filtered by C104 and also goes via R102, a dropper resistor to LED1 which is the power indicator.

Construction

The construction of the receiver is built on two PCB’s; one is for the power supply and the other is the main radio PCB. All you need do is copy the etching pattern of fig. 4 and either using photo etching or have someone make the PCB for you; you can then refer to fig. 2 for the component overlay.

Start with the wire links first (there’s only one on the main PCB) then the resistors and finally the capacitors taking care with their polarities.

For U2, I would install an 8 pin DIL IC socket and makes the job easier rather than soldering directly to the IC. This gives you the option of replacing the LM386N-1 in the case that something goes wrong and you damage the IC.

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Next, D1/D2 and U1 can be installed taking care of their orientation. On U1, pin 1 is ground (or negative) and D1/D2, the anode is on the left of the TO-92(18) casing.

It would be a good idea to verify this ahead of time before installing these components, especially the varicap diodes D1/D2 by doing a diode test on it first to determine where the anode and cathodes are. Installed in reverse direction to how it should be will result in the circuit failing to tune anything at all.

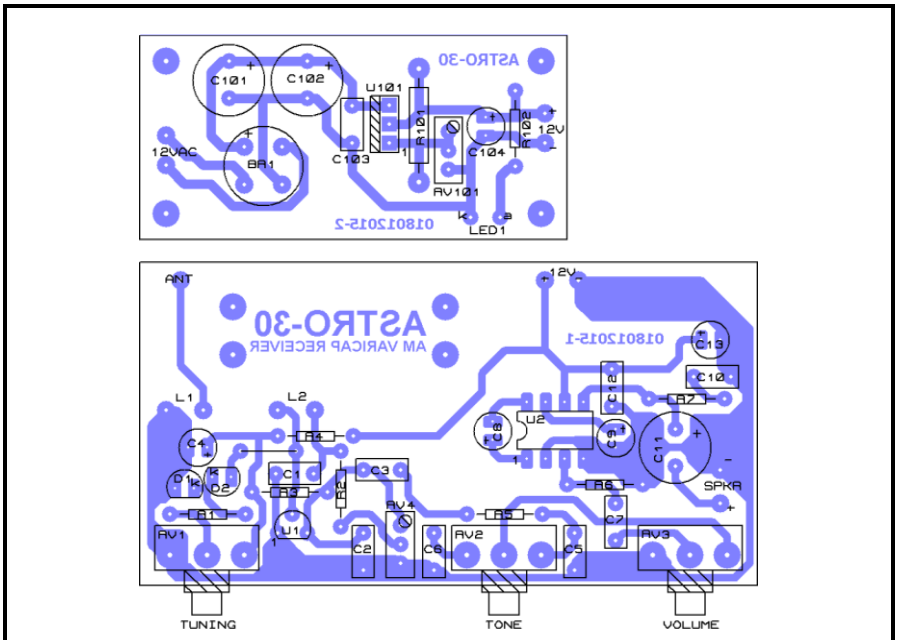


Figure 2 – The printed circuit board overlay diagram for the AM receiver.

The loop stick coil (L1/L2), is made up on a 100mm long ferrite rod using 7 turns of 0.30mm ECW for the antenna coil and 60 turns of 0.30mm ECW for the main coil.

This is achieved by first wrapping a piece of paper around half the length of the rod just long enough to wrap around (loosely) no more than twice on itself. This is then cello taped to stop it for coming apart. You should be able to easily slide this up and down the length of the rod. If you can't, un-tape it and re-tape it a little more loose.

Next, you can begin by taping a length of ECW to the paper around 5mm from its edge leaving yourself around 10cm of wire "hanging-off" the end of the rod. Begin winding 60 turns of ECW for the main coil first, periodically checking that the paper "tube" still slides freely up and down the rod. Try to keep your windings as neat and as close together as possible. Once winding of this coil is complete, place a piece of tape of the windings sticking it to the paper to stop them moving but still allowing the paper to slide on the rod.

Next, wind the 7 turns required for the antenna coil as close as practical to the main coil using the same method as above. The ends of the wires can now be scraped of their enamel, tinned and finally soldered in to the respective holes on the main board.

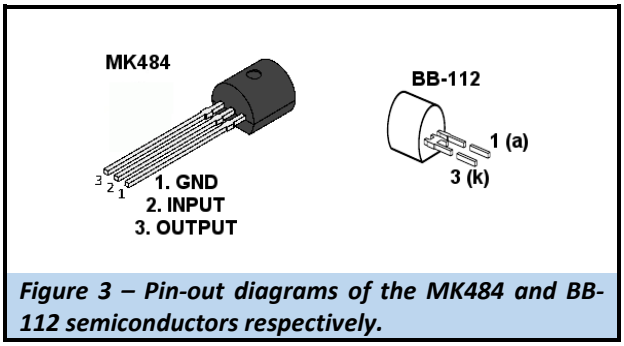


Figure 3 – Pin-out diagrams of the MK484 and BB-112 semiconductors respectively.

Finally, the three 16mm single-gang 10 k potentiometers can be installed and (except for the volume pot) it's not overly critical as to whether they are of linear or logarithmic types.
If you have used an IC socket for U2, now would be a good time to insert the IC taking note of correct orientation. The notch faces towards the tuning pot.

Testing

Testing begins by adjusting the output voltage of the regulator IC101. Connect a suitable AC plug pack adapter to the AC input of the board, apply power and measure the output voltage with a voltmeter. Adjust RV101 until the meter reads around 9.6VDC. This should be more than adequate to power the main board and also allow the 0 – 8V across the varicap diodes (D1/D2) to give the desired frequency coverage. Once you are satisfied that the voltage output is correct, you can connect it the main board and also the speaker.

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Start by rotating the RF set pot (RV4) to around half-mast and the volume pot (RV3) fully counter-clockwise. Connect power and listen for any unusual noises emanating from the speaker. If it starts squealing it's indicative of the circuit oscillating. Disconnect the power and check for solder splashes across tracks or components not soldered in correctly.

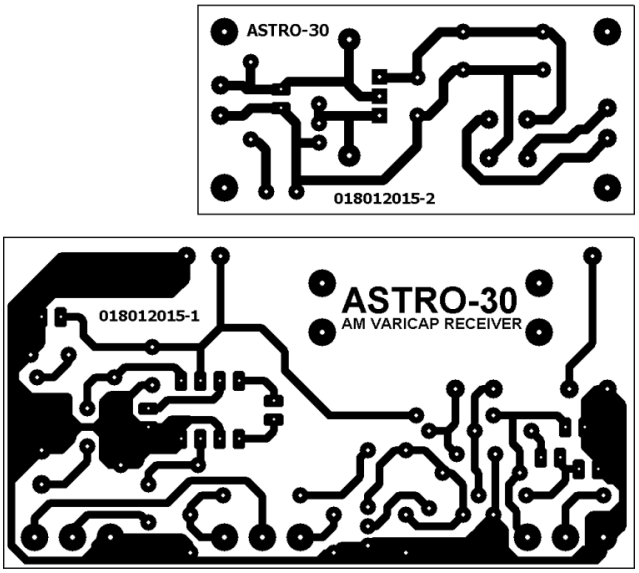


Figure 4 – The etching pattern for the PCB produced here at 1:1 scale for easy printing.

Assuming no unusual noises are present, slowly rotate RV3 up and listen for "static". You should be able to hear the normal AM noise of a radio not tuned to a station (or if you're lucky, depending on the position of RV1, an actual station!). Next, rotate RV1 and see if you can tune anything in. If you hear nothing and after playing with RV2 for a while, switch off and check you have soldered everything in the correct place and the correct way around.

At this point, it may be necessary (if you haven't already done so) to check that D1's anode is definitely on the left of the device. This can be verified with a multi-meter set to the ohms or diode test scales and should only show a reading one way around. The pin that has the positive probe on it is the **anode**. If it is installed the incorrect way around in the circuit (i.e.: forward-biased), the variable capacitance effect of the diode will **not** be present.

Adjust the RF set pot until the sound is as loud and clear as possible; this is not overly critical and is purely up to how you want it to sound.

Next, you can now adjust the lower end of the tuning range which will require another AM receiver to verify what station is at the lowest end of the tuning range (531 kHz). Slide the paper "tube" slowly up and down the rod and you will notice that the tuning will "shift". Re-adjust tuning pot RV1 to re-tune the station in. Repeat this until RV1 is tuning that station as far counter-clockwise as possible. Once satisfied, you can zip tie the rod to the circuit board via the four holes provided.

It's now time to move on to the final hardware construction phase.

Final assembly

Final assembly begins by fitting out the plastic housing by drilling its front and rear panels and the necessary holes on the lid for the speaker. The enclosure (Jaycar catalogue number HB5970) measures 140 mm wide by 110 mm deep and 35 mm high and each panel measures 134 mm wide by 30 mm high. Fig. 5 shows the artwork for both the front and rear panels which can be printed on to A4 sticker paper (purchasable at most office supply stores), cutting them out with a pair of scissors and sticking them carefully to each panel.

You could do one of two things; use the original plastic panels that come with the enclosure, or you could cut them out of a sheet of 1 mm thick (18 gauge) aluminium. The latter would probably be the better choice (even if it involves more effort) for two reasons. One, the metal will give the pots something to earth to acting as a ground plane and two, its less messy to drill. Plastic has the tendency, together with the paper sticker, to melt and burr.

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After deciding what type of material to make the panels out of, you can use the stickers that you have affixed to each to assist in drilling. Start with the smallest drill bit first (and if using aluminium, centre-punch each hole) and then step it up to the final size. The LED hole on the front panel should be drilled out to 4 mm and you can use an LED clip to mount the LED to the panel. The pots are drilled out to around 7 mm and take note that there are **no** pilot holes drilled to accept the dowels on the pots. These will have to be broken off the pots prior to marrying the PCB to the panel.

The power switch is of a miniature panel mounted toggle variety and the hole can be drilled out to around 7 mm. The antenna hole on the rear panel is of an RCA type connector and these usually have a 7 mm mounting hole.

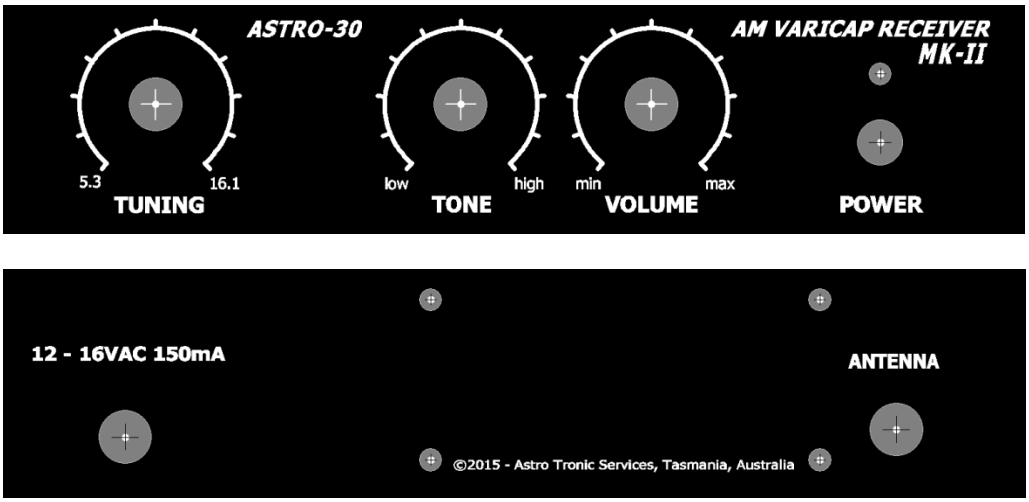


Figure 5 – Front and rear panel artwork of the receiver produced here at 1:1 scale for easy printing.

The DC socket is drilled out to around 8 mm and is of the lock-nut bulkhead (5.5 mm barrel with a 2.1 mm centre) with a switched negative variety. Basically, everything is drilled out in steps until they fit snuggly in their respective holes but don't need any extra force to insert them.

On the front of the bottom panel of the case, there are four circuit board mounting stand-offs (and the two in the middle at the rear) which will have to be removed otherwise it will interfere with the PCBs. These can be nicked of with a sharp Stanley knife, miniature hacksaw or a pair of side-cutters and sanded down flush, taking care not to damage to front tongue that accepts the front panel.

Next, you can move on to the drilling of the speaker holes and I have provided a rough sketch of the drilling plan in fig. 6. Use this as a guide and this is solely dependent on what size speaker you're using. In my case, I'm using a 76 mm 1W 8 ohm speaker which just fits inside the case (Jaycar catalogue number AS3006). Again, start with the smallest drill bit first which will assist in drilling roughly central in the plastic and move up to the final size. A size of around 4 mm should be adequate for this purpose. Once cleaned up and de-burred, the speaker can be glued in to its new home on the inside of the lid using some Quik-grip or contact adhesive cement and left to dry.

Keep all wires short as possible to prevent binding inside the case and also from picking up stray noise. The AC connector socket has the "negative" or barrel portion of it wired directly to the power supply board's AC in and the tip is wired to the power switch. The power switch is then wired back to the power supply board's AC in. The LED is wired to its respective location on the PCB via two lengths of wire and with heatshrink around the anode and cathode leads of the LED to keep them from touching and also to keep them neat.

The DC output should be wired to the main board (if not all ready) with short wires as well. It's a good idea to twist the negative and positive wires around each other to prevent noise pickup/injection.

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Wire a very short, as possible, wire between the antenna connection and the associated banana socket connector. Finally, you can wire the speaker with reasonably short wiring to keep things neat to its respective location on the main board. Now would be a good time for a final power-up test to make sure the device still works.

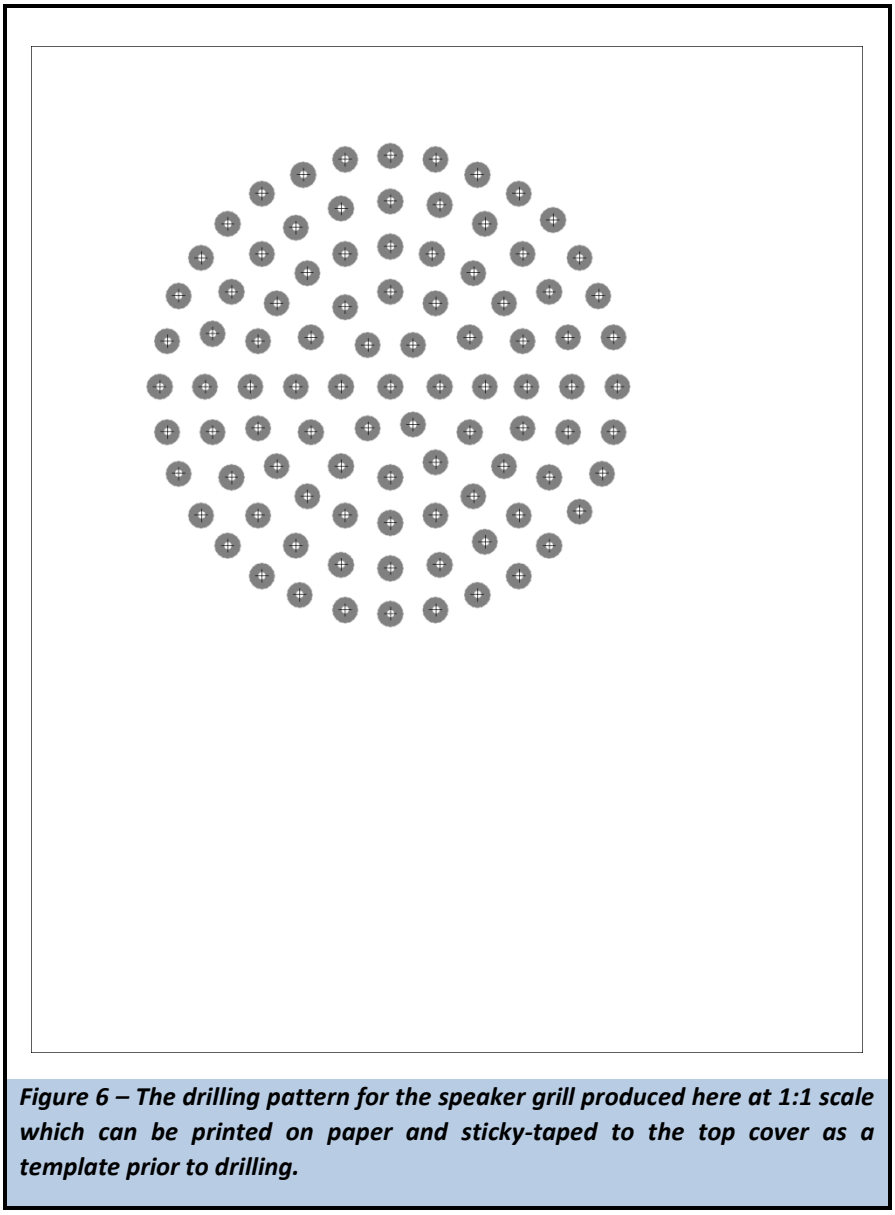


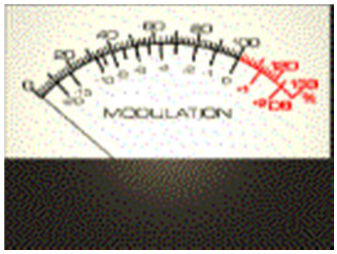
Figure 6 – The drilling pattern for the speaker grill produced here at 1:1 scale which can be printed on paper and sticky-taped to the top cover as a template prior to drilling.

Conclusion

In conclusion, this project should only take around four to five hours to complete which includes all of the drilling of the hardware. I hope you enjoy building this project as much as I have presenting it here and I also hope that the construction details presented here are detailed enough. Enjoy! – **TheAstro30**

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How to build a micro transmitter



Tetsuo Kogawa

Why was this site established?

Because transmission technology is esotericized and I believe that it provides exciting possibilities to art.

- **Diagrams**
  - The simplest FM radio transmitter (for artistic or experimantal use) with FAQ (How to build and tune up)
    - Components (registers, capacitors, coil, trimcap, and so on).
    - Basic tools (soldering iron, tweezers, wire cutter, and epoxy[hard glue]).
    - How to build?
  - The simplest TV transmitter (for artistic or experimantal use) with a theoretical introduction (why simple and why transmitter?)
  - The simple but practical TV transmitters with sound (you need some technical skils and proper tools)
  - The 1-3 watt FM transmitter (You need a power meter and a frequency counter: otherwise don't try to build this model.)
    - Schematics: (1)PDF (2)JPG (3)Symbolic (4)VRML (needs VRML-Player)
    - Components: list pictures and tips
    - FAQ (How to build and tune up)

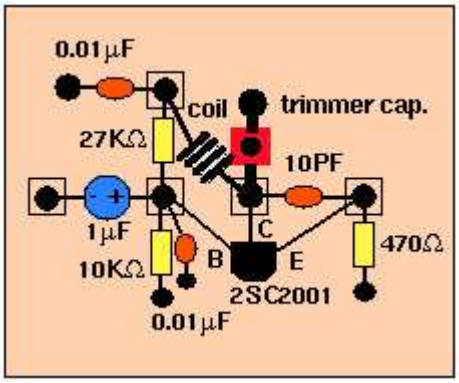
- **Tools**
  - Basic
  - Power meter
  - Frequency Counter (recommended)

- **How to build**
  - Step by step pictorial manual Movies(WMV) Movies(Quicktime)

- **Antenna and How to operate**
  - How to make a simple, inexpensive and effective Antenna?: (1) HTML+JPG (2)PDF
  - How to stabilize the supplied power?

- **Histories**
  - The earlier "private" workshop to build a transmitter, June 3, 1990 Video [MP4, 41.3MB]
  - The first "public" workshop to build a transmitter, April 28, 1991 Video [RealMedia]
  - The first Workshop in the U.S. at Paper Tiger Television, November 4, 1991 Video [RealMedia]
  - Other Transmitter Workshops: see the "Streaming Media Archives" -->

How to build the simplest FM transmitter?



This tiny transmitter has several "defects": smaller radius of the service area, lower quality of the sounds and the relatively unstable frequency. These can be considered as a compromise to easily have your own transmitter for the time being or as a more positive choice. These "defects" are only from the perspective of conventional transmission such as "clear stereo sound to receive anywhere". Artist could change these to another directions. Whether or not, you can experience a *convivial wireless imagination* by this transmitter.

The schematics:

- **the basic unit:(pdf) (jpg)**

  Given the most simplest model, it is a bit inconvenient to change the transmitting frequency: change the gap of the coil (closer gap -->lower frequency; looser-->higher).

- **the standard model:(pdf) (jpg)**

  In this version, you can change the frequency by the trimercap (variable capacitor). If you can have a variable capacitor, I recommend you to choice this version.

- **the standard model with a microphone: (pdf) (jpg)**

  This has a condenser microphone unit in it. Every version could use the same circuit. Usual microphone has not enough output to this unit, but condenser microphone unit can drive this system. See how simply it is installed--->picture

The list of components: registers, capacitors, transistor and etc.

The basic tools: soldier (less than 30 watts), wire-cutter, tweezers, and etc.

How to build and solder? A visual manual.

Pictures of the finished model: Standard model

FAQ

didn't work well ; stabilize the voltage ; extend the area copper plate change the frequency trimmer cap alternative transistor make the coil microphone iPod

problem why need a power meter and a frequency counter

Q: The transmitter works but the airwaves are too weak. I think there might be something wrong.

A: Every transmitter using the minimum parts like this has to have harmonic signals and "spurious". So you may sometimes not receive the authentic signal. Leave your radio receiver far at least three meters from the transmitter. Don't attach any cable to the antenna terminal. Then turn the trimcap slowly. The frequency will change and you will find the most strongest signal. (See "the another Q&A below) In the 1.1 version with a variable capacitor to change the frequency, turn it very slowly until you get the most strongest signal at your radio. If you don't get, reduce the turn of the coil from 4 upto 2. When you use a variable capacitor over 10PF such as 20, 50 PF, 4 turns (I indicate in the schematic) would be too much. If you have a frequency counter, it would be easy to tune up the coil.

Q: I love the simplest transmitter. I wonder if this transmitter could be used for a practical Mini FM transmission.

A: The main problem is that the frequency is unstable. This is interesting from the perspective of radio performance, though. As the voltage of the battery is deteriorated, the transmitting frequency will be changed. In order to avoid it, you may use a stabilized power supply. It would be a bit expensiver. You don't mix with a "AC adapter". When you use a ordinary "AC adapter", you should add a voltage regulator semiconductor for 9-12 volts such as "7809" or "7812". The simplest schematic is here (jpg).

Q: This transmitter can cover only a modest radius. Is it possible to extend it?

A: If you connect it to the proper antenna, you can do it. How to make an antenna is here (pdf). For this, you have to use a thicker coaxial cable between the transmitter and the antenna. The thinest one can be used only for 1-2 meter extension. Think of the thickness of waterpipe and the length. Long extension increases the loss.

Q: I can't get "copper-coated plate". What else?

A: The schematic is supposed to use copper coated plate that is familiar with my design. When it is difficult to obtain, you can use even "porous circuit board" (jpg) that is popular in electronic hobby. The schematic is here (gif). I suggest you use the reverse side and directly solder the parts to it because this is convenient for your possible cut-and-paste and would be effective for your electro-magnetic performance.

Q: Can I change the frequency of the "basic" version? How?

A: In order to change the transmitting frequency without the trimcap, you a bit spread or compress the gap of the coil. When you do this operation, you have to have some distance (at least 3 meter) between the transmitter and the receiver

(FM radio): otherwise you may be disturbed by many "spurious" (harmonic signals) and may not find the main one you want. That's why the best thing is to use a frequency counter.

Q: What is "trimmercap" in "the changable-frequency version"?

A: Don't mix it with "variable capacitance diode (varicap)" for the 1-3 W transmitter. What we need here is only for manually varying the capacitance from (theoretically) 0 to 20 PF max. There are the various types and appearances. The classical one consists of tiny brass plates and ceramics. Some of the pictures are here.

Q: I can't obtain the transistor 2SC2001. What is compatible with it?

A: There should be many replacements: 2SC2003, 2SC458, 2SC1973, 2SC3358, 2SC3580, 2SC3605, 2SD734 and so on. The European or American models such as BC337 or NTE123AP can be used, but be careful of the different position of the pins (E=Emitter, C=Collector and B=Base) depending the semiconductors. The circuit that I designed uses 2SC2001 because it is cheap and very obtainable in Tokyo.

Q: How to make a coil by myself?

A: Prepare a 5mm diameter cylindrical material and enameled wire of 0.8 mm diameter. The movie (WMV 280KB and MPEG 1.2MB) shows how to do.

Q: I prefer to use a tunable mold coil. What kind of coil can I use?

A: I stopped showing the schematic with it because the tunable mold coil (3-4 turns) has become less obtainable now. If you can get it, just install it instead of a hand-made coil WITHOUT the trimmer capacitor.

Q: Can I build transmitter that a microphone is attached to in it?

A: You can get a "condenser microphone unit" in low price. Using this, you can build it very easily. Check the partial diagram (pdf) and the complete diagram(pdf) of the simplest transmitter with a microphone in it. When this is acrobatically soldered, here(jpg) is the example.

Q: When I connect my iPod to the audio input of this transmitter, it suddenly stops to work. What's happening?

A: The ealier model of iPod has an automatic shut-down system in it. When you pull out the plug of your headphone, it automatically stops working. When the left and right channels are short-circuited, the same thing happens. Presumably, you use a stereo cable and solderd the left (white) and right (red) lead together. Please use the left channel lead (white) only. Usually the left output is compatible with mono audio. If you, however, insist to mix the left and right output of your audio source into the transmitter, make a simple "interface" like this by two sets of 1 kiro ohm registers.

Parts List of the Most Simplest Transmitter

Registors:



1 10K Ohm 1/4 -1/8 Watt (brown-black-orange)
1 27K 1/4 -1/8 Watt (red-violet-orange)
1 470 - 500 1/4 Watt

Capacitors:



1(2) 10PF Ceramic
2 0.01MF (also indicated as 103) Ceramic
1 1 - 10 MF Electrolyiic

Coil:



1 4 turns by 0.8 mm enamel wire



Trimmer capacitor:
1 10 - 20 PF
(there are various shapes but keep the value-10_20PF)



Copper-clad circuit board:
1 plate of 4 x 5 cm (minimum) and 0.5-1.0 mm(thick) and 4(5) small squares (5 x 5 mm)



Audio cable:
30 - 50 cm lengh of audio cable with mini-mono (or stereo) 3.5mm plug. When you use mini-stereo cable, you must use the left channel (white) only.

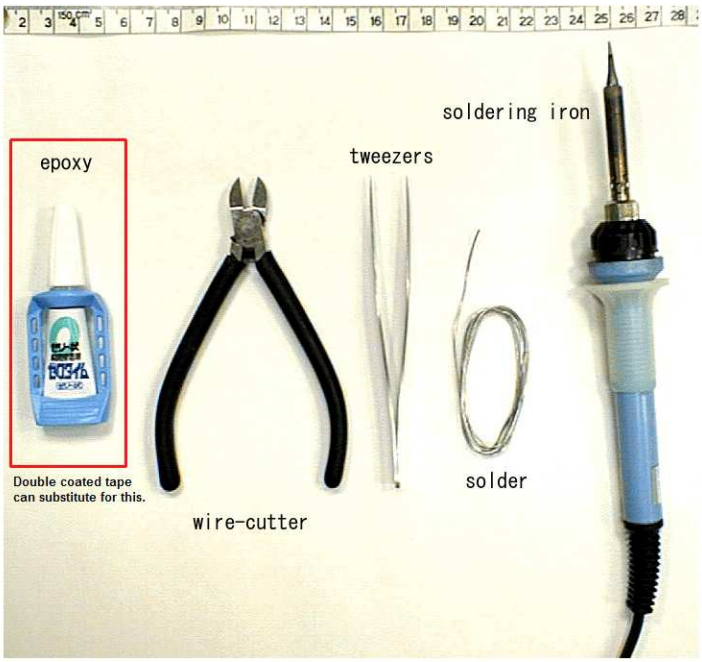
9 volts Battery and the snap connector



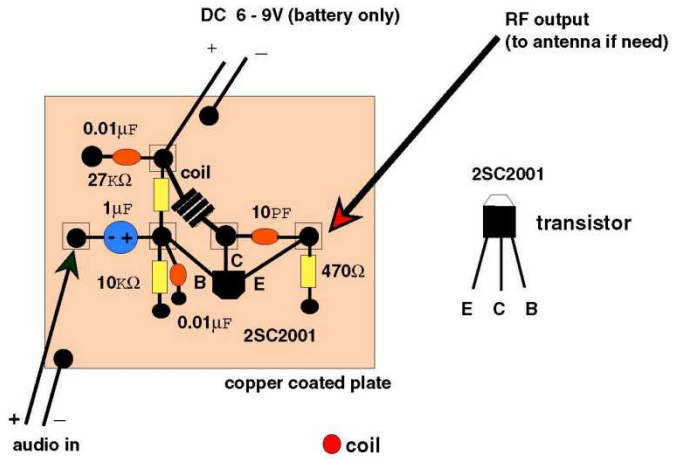


The basic tools for building the simplest transmitter:

- **Soldering Iron (20-30W type; don't use a powerful one such as 60W. It will destroy the parts.)**
- **Solder (Usually this is sold as a roll but you need only 30 cm for one set to build).**
- **Tweezers: good example unsuitable one**
- **Small Wire Cutter**
- **Five-Minute Epoxy (the strongest type for metal and chinaware to glue)(Instead, you can use "Double sticky" or "Double coated tape" too.)**



Making the simplest Transmitter



● soldered point:

: direct to the ground

: insulated from the ground

● coil

3 - 4 turns by coated 0.8 mm wire

5 - 7mm

● registers

470 Ω *(yellow-violet-brown)*

10K Ω *(brown-black-orange)*

27K Ω *(red-violet-orange)*

● capacitors

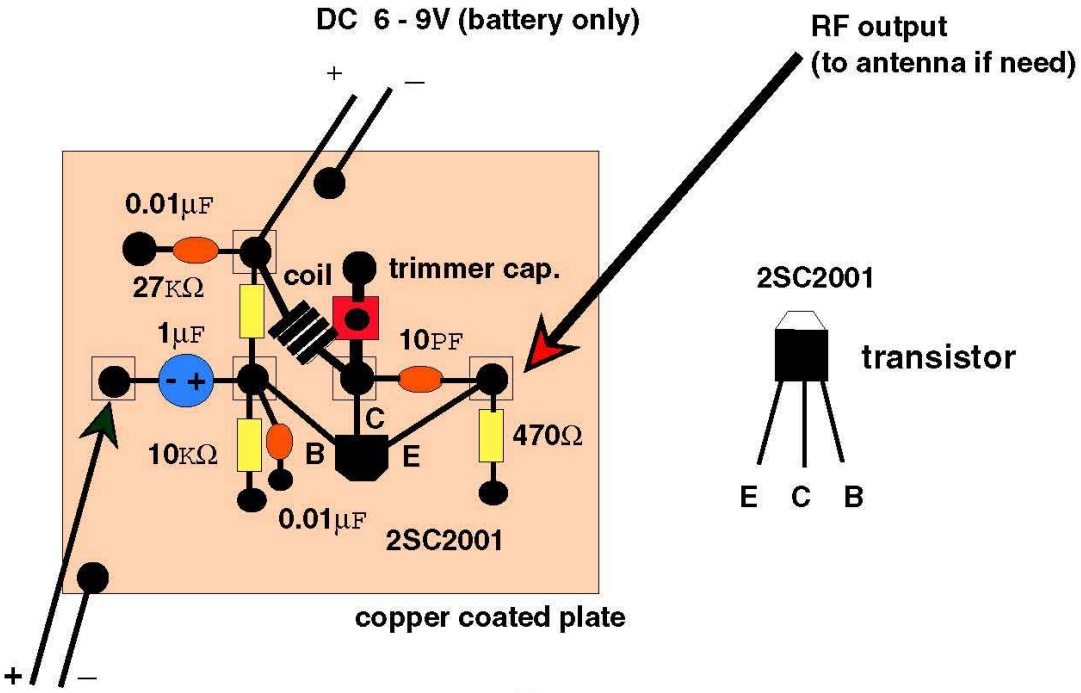
10 PF

0.01 μF *(103)*

1 μF

2005-03-16 by Tetsuo Kogawa

Making the simplest Transmitter



- soldered point:
  - : direct to the ground



  - : insulated from the ground



- coil
  - 3 - 4 turns by coated 0.8 mm wire

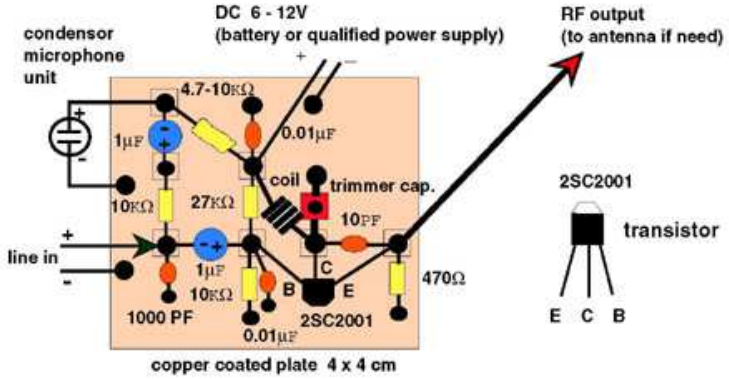

5 - 7mm



- registers
  - 470 Ω *(yellow-violet-brown)*
  - 10K Ω *(brown-black-orange)*
  - 27K Ω *(red-violet-orange)*
- capacitors
  - 10 PF
  - 0.01 μF *(103)*
  - 1 μF
- trimmer capasitor 20PF

2005-03-16 by Tetsuo Kogawa

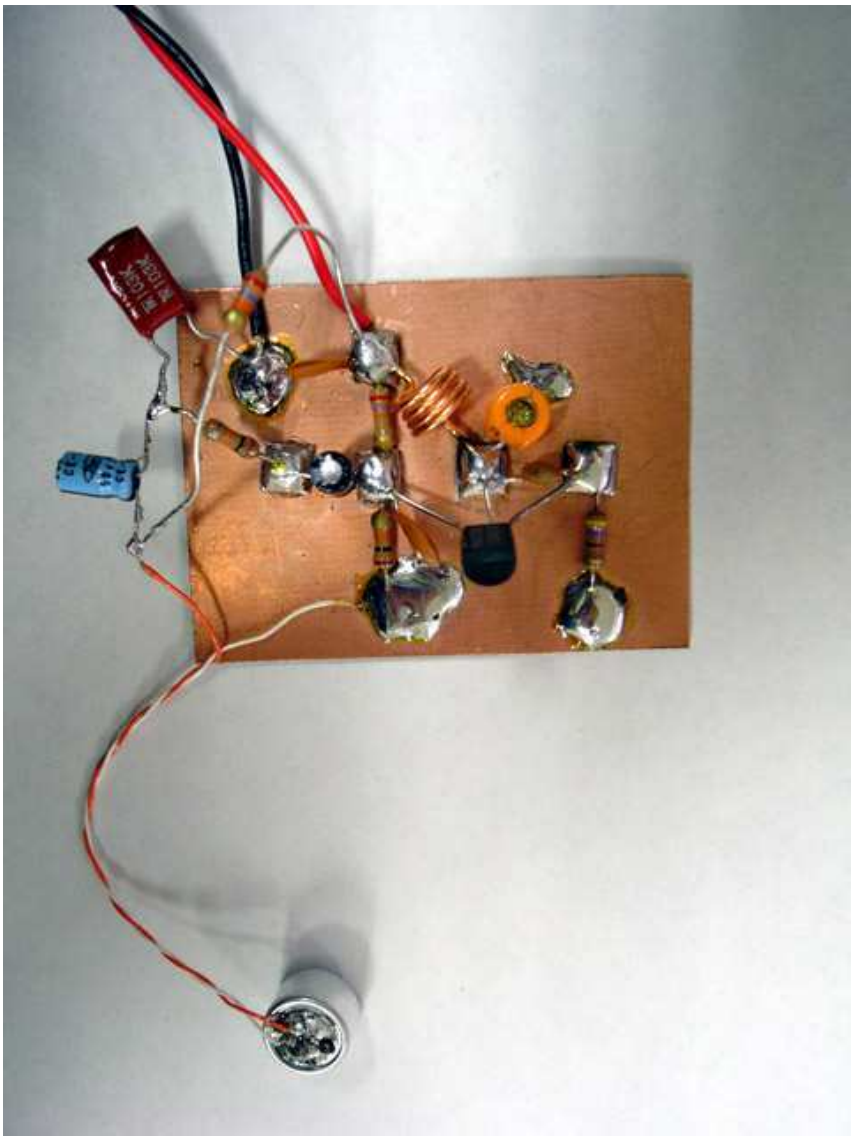
Making the simplest Transmitter with a microphone



- soldered point:
  - : direct to the ground
  - : insulated from the ground
- Solder every part at the shortest distance.

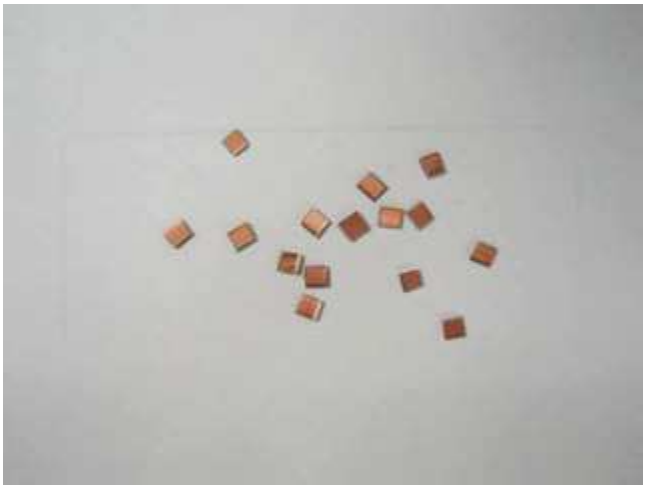
- coil
  - 3 - 4 turns by coated 0.8 mm wire
  - 5 - 7mm
- registers
  - 470 Ω *(yellow-violet-brown)*
  - 10K Ω *(brown-black-orange) 2 pieces*
  - 27K Ω *(red-violet-orange)*
- capacitors
  - 10 PF
  - 0.01 μF *(103)*
  - 1 μF 2 pieces
- trimmer capasitor 20-50PF
- condensor microphone unit
- 4.7-10KΩ

2006-01-15 by Tetsuo Kogawa



How to build and solder?

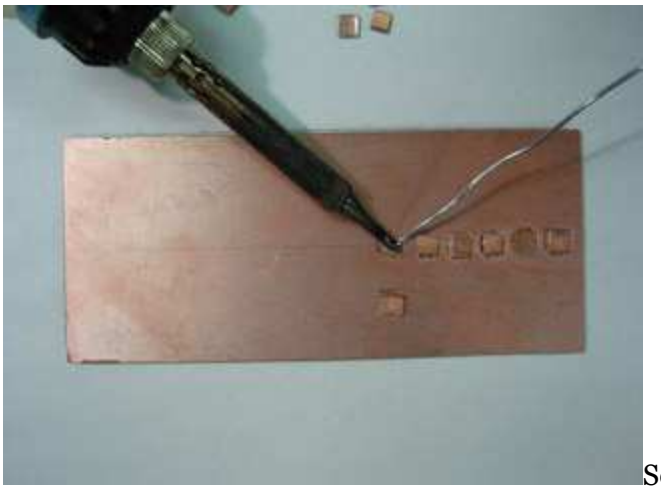
The pictures are not of the most simplest transmitter but how-to is the same.

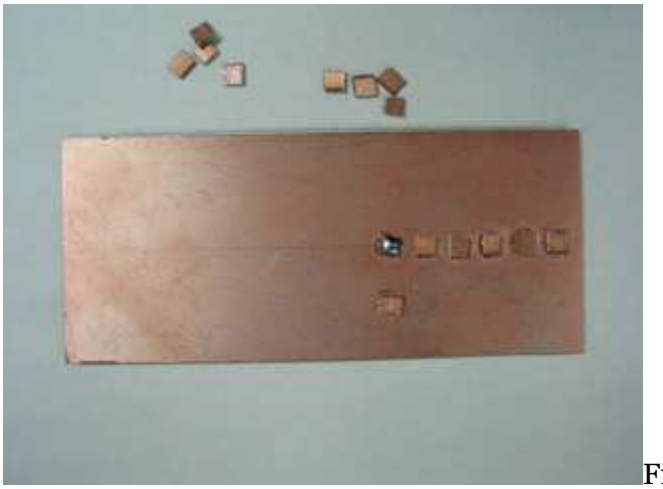


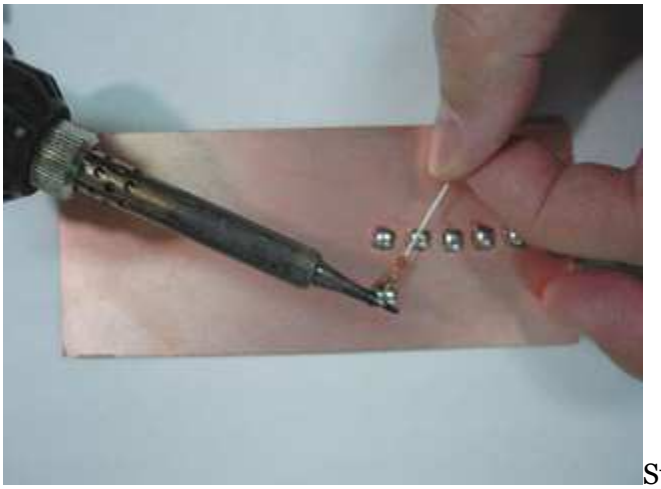
Make 5 x 5 mm squares.
This size is not random nor appearance of good shape but is designed by the theory of "micro strip line" circuit.

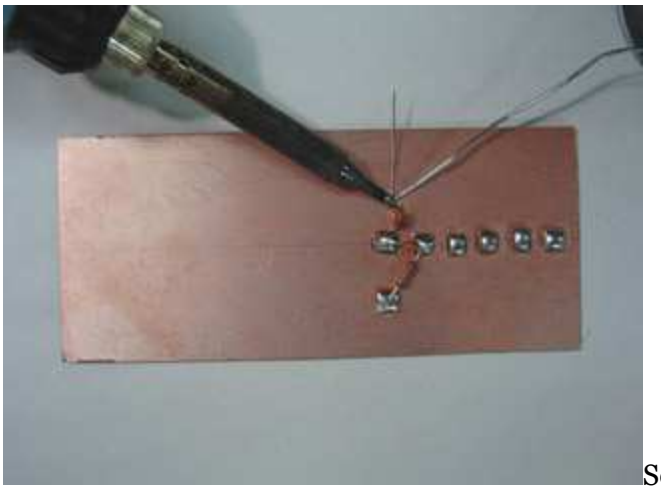

Drop a glue gel. The glue must be strong enough for fasting the squares on the board.

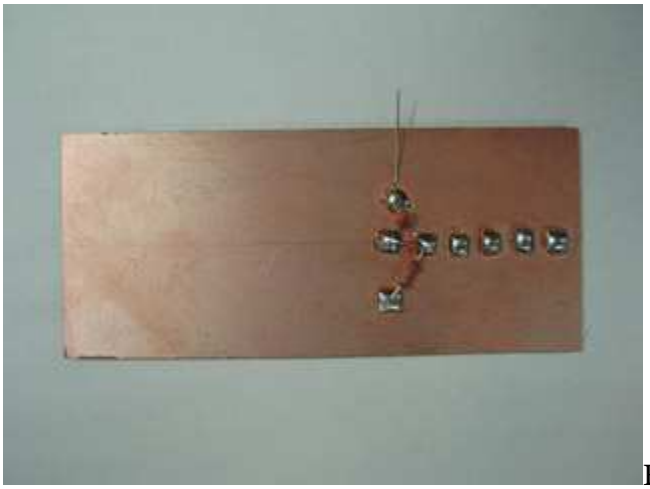

Paste a square on the copper-plated board one by one.

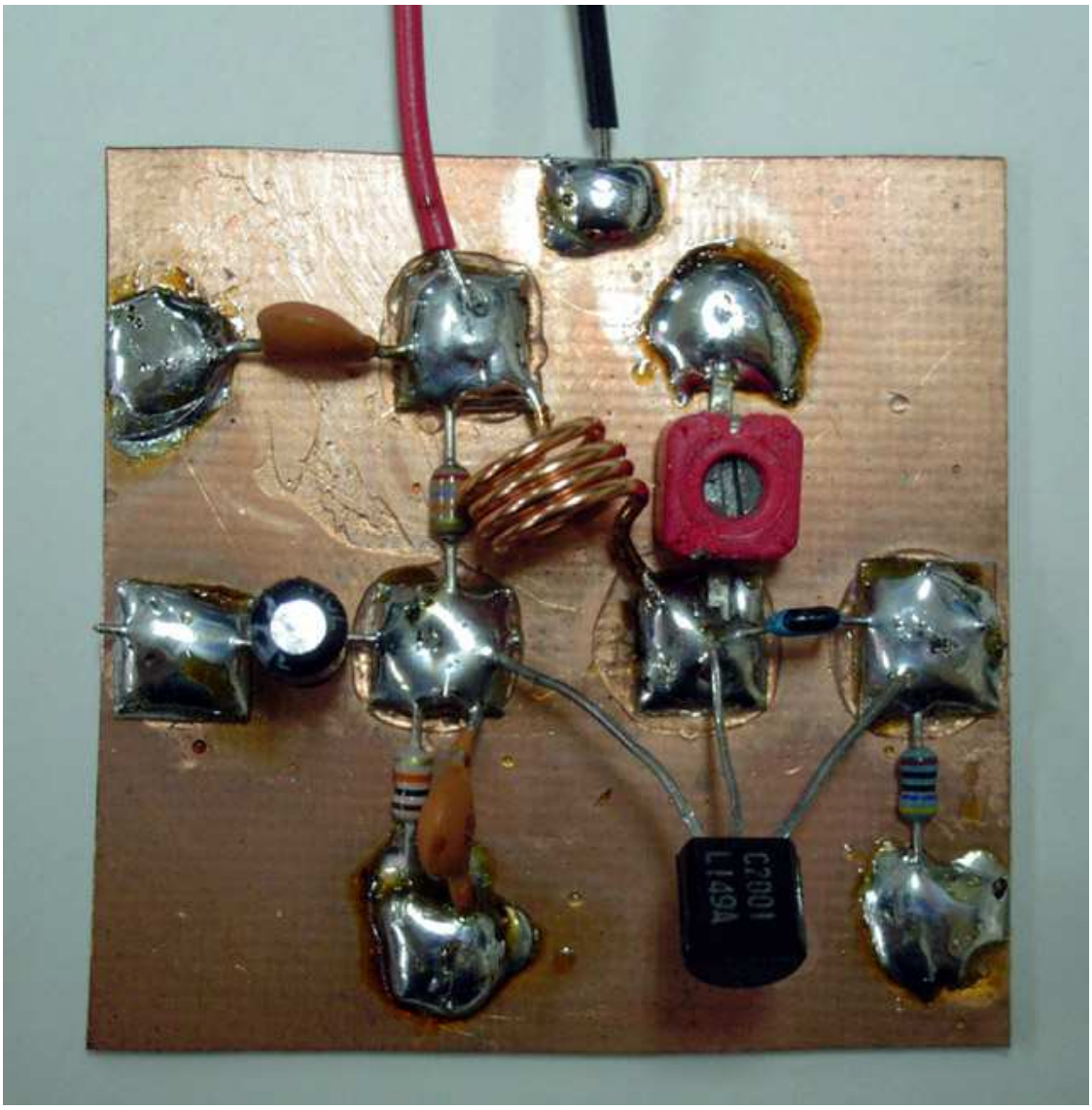

Solder on the surface of the square.


Fill the surface by solder.

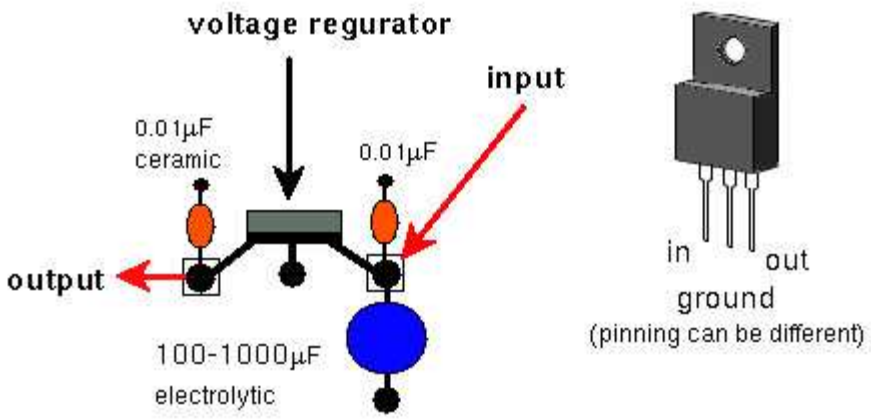

Start to solder each components one by one.

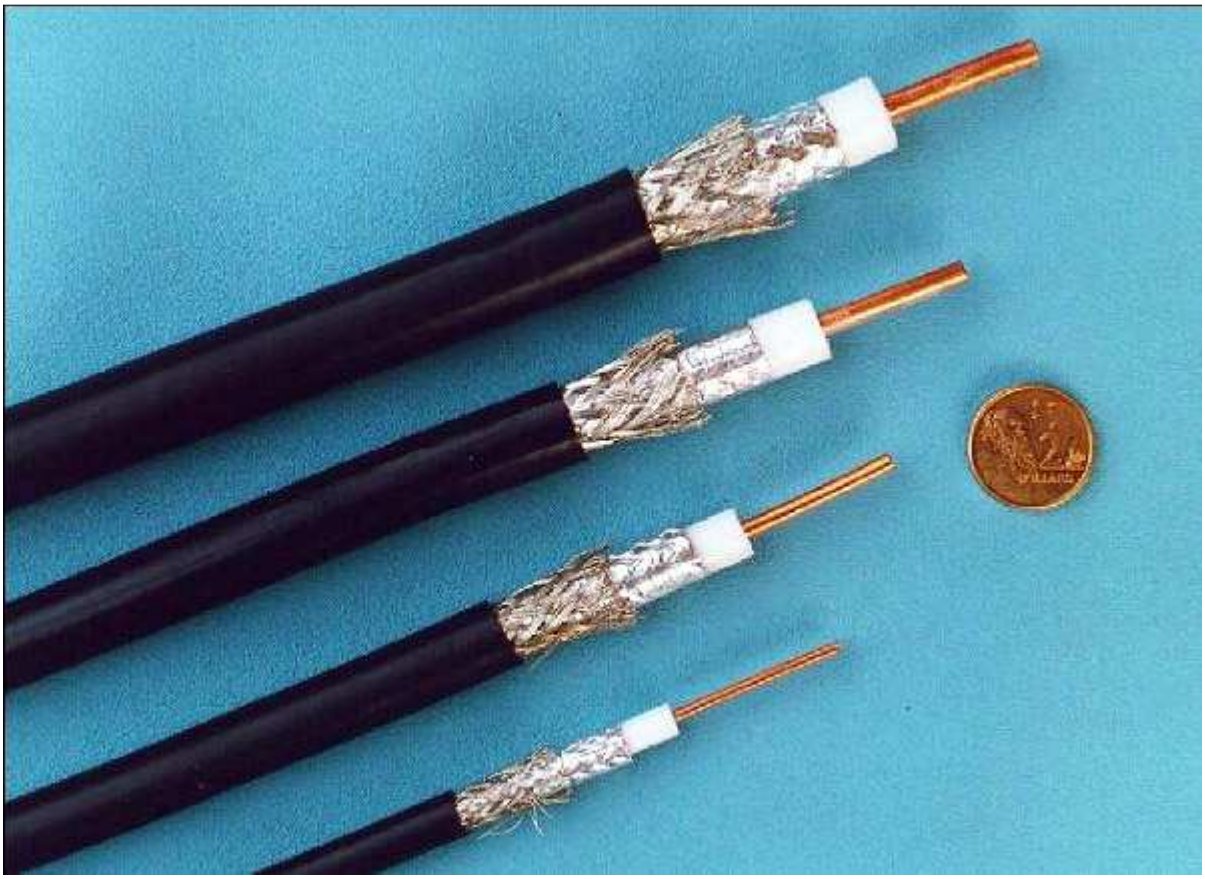

Solder on the ground.


Every lead

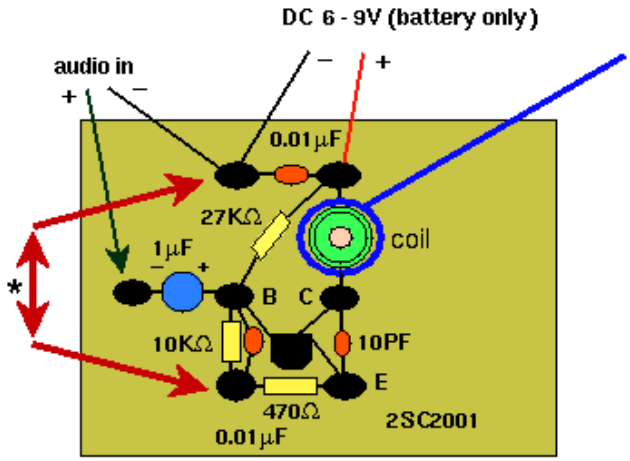

C2001
L149A


J.A.L.
REGULATED
DC POWER SUPPLY
Off
POWER
Output
13.8VDC
6
AMP
MODEL NO
RK-PS126

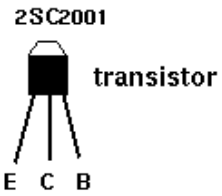

voltage regurator
input
0.01µF
ceramic
0.01µF
output
100-1000µF
electrolytic
in
out
ground
(pinning can be different)



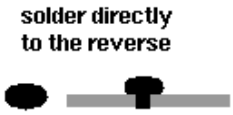
Making the simplest Transmitter



antenna
(just bind the coil by a 50-80 cm coated wire)



use the reverse of a porous circuit board



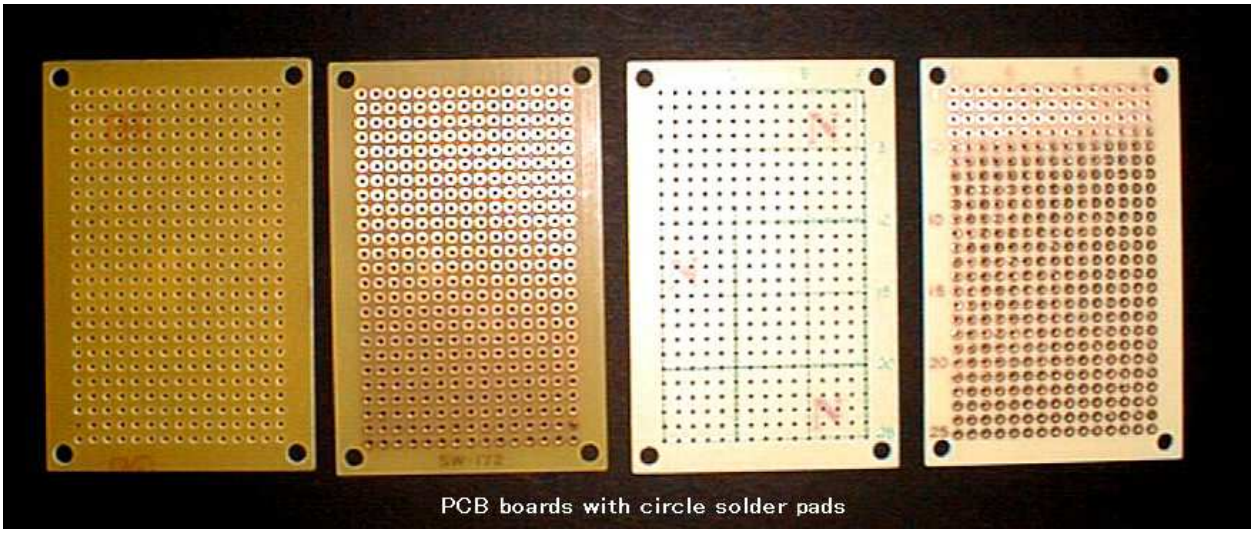
* Short-circuited at the back usibg a cable

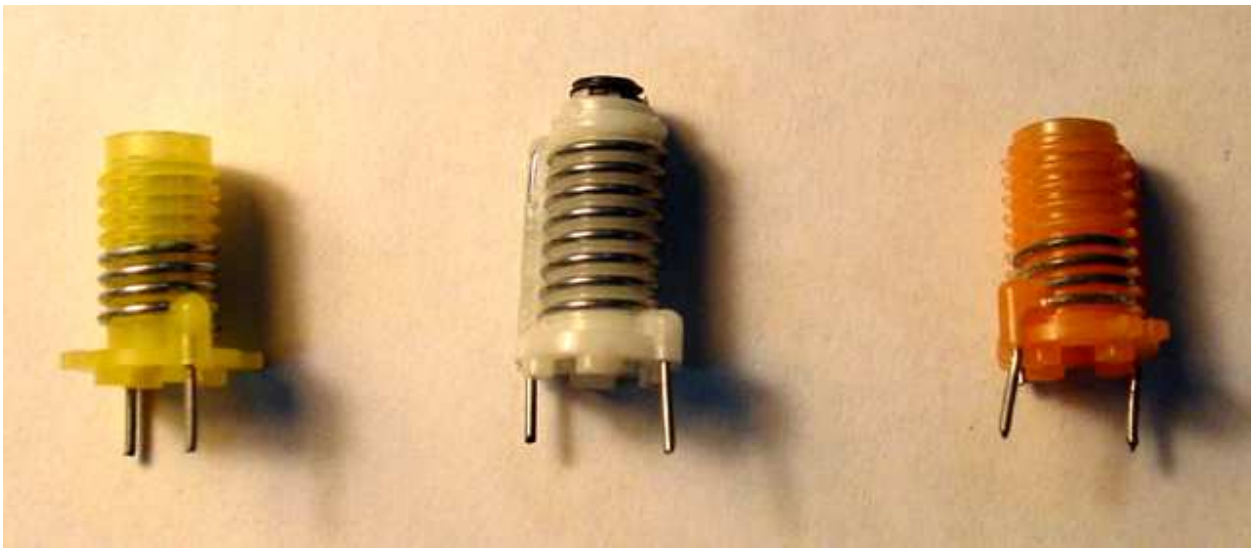
◆**coil**
- 8.5 - 12 turns

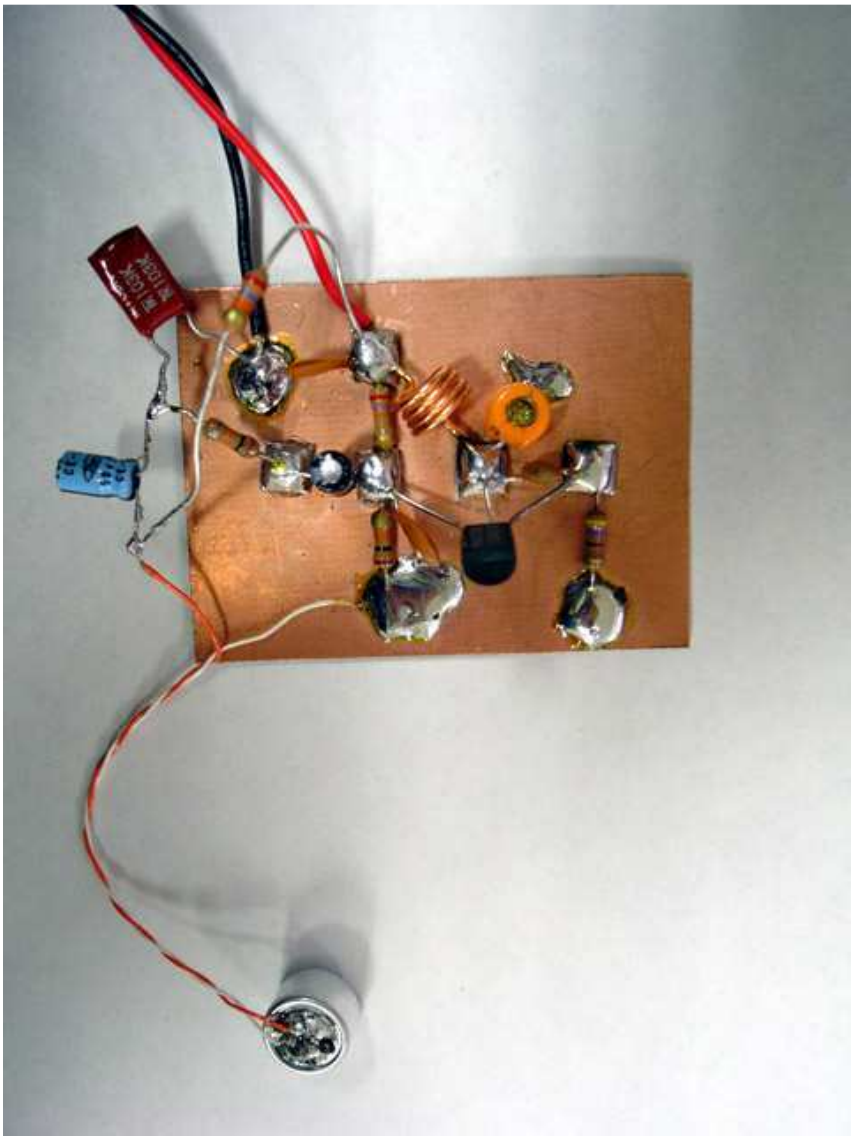
◆**registers**
- **470 ohm** (yellow-violet-brown)
- **10K ohm** (brown-black-orange)
- **27K ohm** (red-violet-orange)

◆**capacitors**
- 10 PF
- 0.01 MF (103)
- 1 MF

2002-03-26 by TK

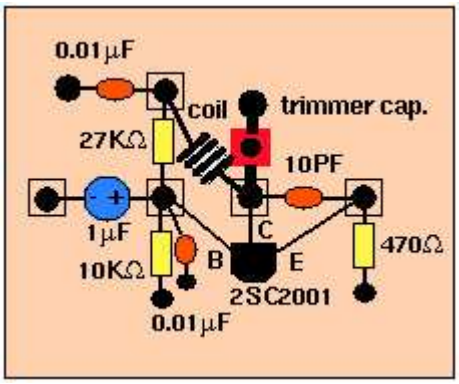

PCB boards with circle solder pads







How to build the simplest FM transmitter?



This tiny transmitter has several "defects": smaller radius of the service area, lower quality of the sounds and the relatively unstable frequency. These can be considered as a compromise to easily have your own transmitter for the time being or as a more positive choice. These "defects" are only from the perspective of conventional transmission such as "clear stereo sound to receive anywhere". Artist could change these to another directions. Whether or not, you can experience a *convivial wireless imagination* by this transmitter.

The schematics:

- **the basic unit:(pdf) (jpg)**

  Given the most simplest model, it is a bit inconvenient to change the transmitting frequency: change the gap of the coil (closer gap -->lower frequency; looser-->higher).

- **the standard model:(pdf) (jpg)**

  In this version, you can change the frequency by the trimercap (variable capacitor). If you can have a variable capacitor, I recommend you to choice this version.

- **the standard model with a microphone: (pdf) (jpg)**

  This has a condenser microphone unit in it. Every version could use the same circuit. Usual microphone has not enough output to this unit, but condenser microphone unit can drive this system. See how simply it is installed--->picture

The list of components: registers, capacitors, transistor and etc.

The basic tools: soldier (less than 30 watts), wire-cutter, tweezers, and etc.

How to build and solder? A visual manual.

Pictures of the finished model: Standard model

FAQ

didn't work well ; stabilize the voltage ; extend the area copper plate change the frequency trimmer cap alternative transistor make the coil microphone iPod problem why need a power meter and a frequency counter

Q: The transmitter works but the airwaves are too weak. I think there might be something wrong.

A: Every transmitter using the minimum parts like this has to have harmonic signals and "spurious". So you may sometimes not receive the authentic signal. Leave your radio receiver far at least three meters from the transmitter. Don't attach any cable to the antenna terminal. Then turn the trimcap slowly. The frequency will change and you will find the most strongest signal. (See "the another Q&A below) In the 1.1 version with a variable capacitor to change the frequency, turn it very slowly until you get the most strongest signal at your radio. If you don't get, reduce the turn of the coil from 4 upto 2. When you use a variable capacitor over 10PF such as 20, 50 PF, 4 turns (I indicate in the schematic) would be too much. If you have a frequency counter, it would be easy to tune up the coil.

Q: I love the simplest transmitter. I wonder if this transmitter could be used for a practical Mini FM transmission.

A: The main problem is that the frequency is unstable. This is interesting from the perspective of radio performance, though. As the voltage of the battery is deteriorated, the transmitting frequency will be changed. In order to avoid it, you may use a stabilized power supply. It would be a bit expensiver. You don't mix with a "AC adapter". When you use a ordinary "AC adapter", you should add a voltage regulator semiconductor for 9-12 volts such as "7809" or "7812". The simplest schematic is here (jpg).

Q: This transmitter can cover only a modest radius. Is it possible to extend it?

A: If you connect it to the proper antenna, you can do it. How to make an antenna is here (pdf). For this, you have to use a thicker coaxial cable between the transmitter and the antenna. The thinest one can be used only for 1-2 meter extension. Think of the thickness of waterpipe and the length. Long extension increases the loss.

Q: I can't get "copper-coated plate". What else?

A: The schematic is supposed to use copper coated plate that is familiar with my design. When it is difficult to obtain, you can use even "porous circuit board" (jpg) that is popular in electronic hobby. The schematic is here (gif). I suggest you use the reverse side and directly solder the parts to it because this is convenient for your possible cut-and-paste and would be effective for your electro-magnetic performance.

Q: Can I change the frequency of the "basic" version? How?

A: In order to change the transmitting frequency without the trimcap, you a bit spread or compress the gap of the coil. When you do this operation, you have to have some distance (at least 3 meter) between the transmitter and the receiver (FM radio): otherwise you may be disturbed by many "spurious" (harmonic signals) and may not find the main one you want. That's why the best thing is to use a frequency counter.

Q: What is "trimmercap" in "the changable-frequency version"?

A: Don't mix it with "variable capacitance diode (varicap)" for the 1-3 W transmitter. What we need here is only for manually varying the capacitance from (theoretically) 0 to 20 PF max. There are the various types and appearances. The classical one consists of tiny brass plates and ceramics. Some of the pictures are here.

Q: I can't obtain the transistor 2SC2001. What is compatible with it?

A: There should be many replacements: 2SC2003, 2SC458, 2SC1973, 2SC3358, 2SC3580, 2SC3605, 2SD734 and so on. The European or American models such as BC337 or NTE123AP can be used, but be careful of the different position of the pins (E=Emitter, C=Collector and B=Base) depending the semiconductors. The circuit that I designed uses 2SC2001 because it is cheap and very obtainable in Tokyo.

Q: How to make a coil by myself?

A: Prepare a 5mm diameter cylindrical material and enameled wire of 0.8 mm diameter. The movie (WMV 280KB and MPEG 1.2MB) shows how to do.

Q: I prefer to use a tunable mold coil. What kind of coil can I use?

A: I stopped showing the schematic with it because the tunable mold coil (3-4 turns) has become less obtainable now. If you can get it, just install it instead of a hand-made coil WITHOUT the trimmer capacitor.

Q: Can I build transmitter that a microphone is attached to in it?

A: You can get a "condenser microphone unit" in low price. Using this, you can build it very easily. Check the partial diagram (pdf) and the complete diagram(pdf) of the simplest transmitter with a microphone in it. When this is acrobatically soldered, here(jpg) is the example.

Q: When I connect my iPod to the audio input of this transmitter, it suddenly stops to work. What's happening?

A: The ealier model of iPod has an automatic shut-down system in it. When you pull out the plug of your headphone, it automatically stops working. When the left and right channels are short-circuited, the same thing happens. Presumably, you use a stereo cable and solderd the left (white) and right (red) lead together. Please use the left channel lead (white) only. Usually the left output is compatible with mono audio. If you, however, insist to mix the left and right output of your audio source into the transmitter, make a simple "interface" like this by two sets of 1 kiro ohm registers.

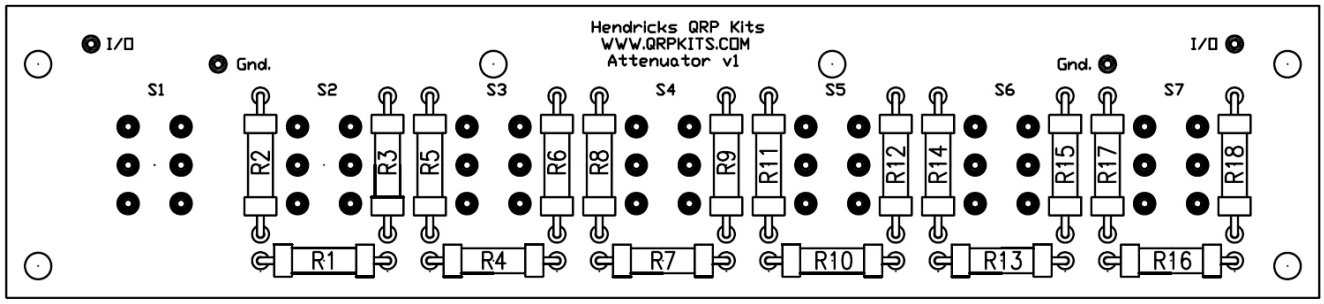
Hendricks 41dB Step RF Attenuator



- **First, familiarize yourself with the parts and check for all the components**.

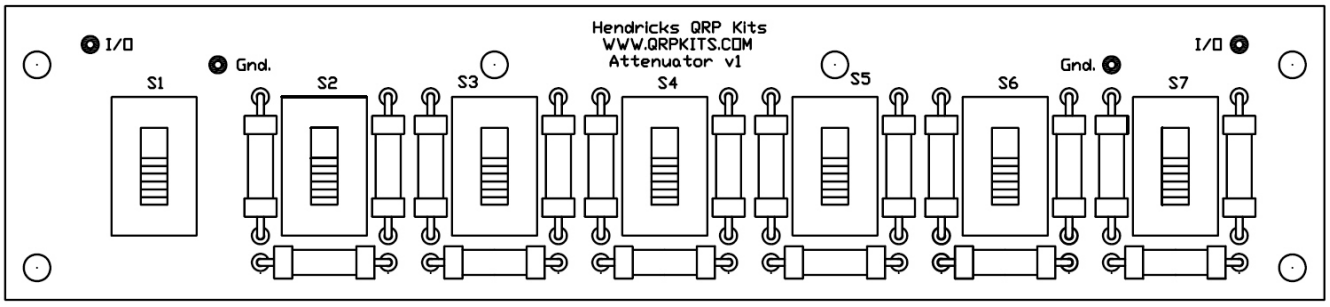
Parts Inventory

R1 – 6.2 ohm, 2W, resistor (blue-red-gold-gold)
R4 – 12 ohm, 2W, resistor (brown-red-black-gold)
R7 – 18 ohm, 2W, resistor (brown-gray-black-gold)
R10 – 33 ohm, 2W, resistor (orange-orange-black-gold)
R17 & R18 – 68 ohm, 2W, resistor (blue-gray-black-gold)
R13 – 75 ohm, 2W, resistor (violet-green-black-gold)
R14 & R15 – 100 ohm, 2W, resistor (brown-black-brown-gold)
R11 & R12 – 200 ohm, 2W, resistor (red-black-brown-gold)
R16 – 270 ohm, 2W, resistor (red-violet-brown-gold)
R8 & R9 – 300 ohm, 2W, resistor (orange-black-brown-gold)
R5 & R6 – 470 ohm, 2W, resistor (yellow-violet-brown-gold)
R2 & R3 – 910 ohm, 2W, resistor (white-brown-brown-gold)
7 – DPDT slide switches
2 – BNC female chassis connectors
4 - 4-40 x 1/4" undercut Philips flat head screw
6 - 4-40 x 1/4" Philips head screw
4 – rubber feet
1 – decal set
1 – aluminum chassis
12” – Teflon hook-up wire

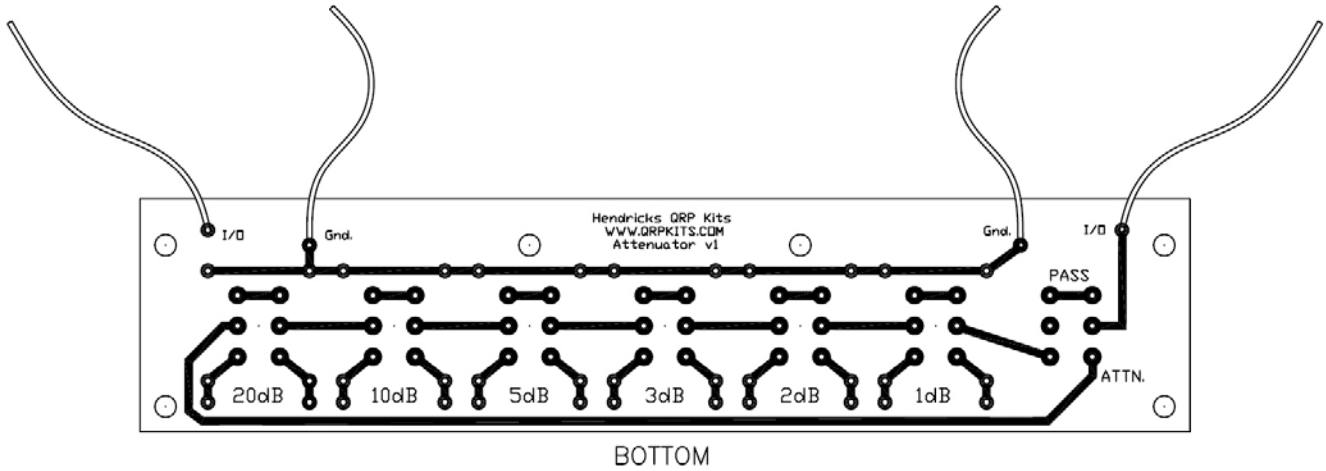


Begin by installing resistors R1 thru R18 on the side of the board with the silk screening.

Note: These 2 watt resistors have color codes that are difficult to read, due the texture and color of the resistor. It is best to check the value before installing and soldering. They can be difficult to exchange.



Next, install the DPDT slide switches, S1 thru S7 on the same side as the resistors.



BOTTOM

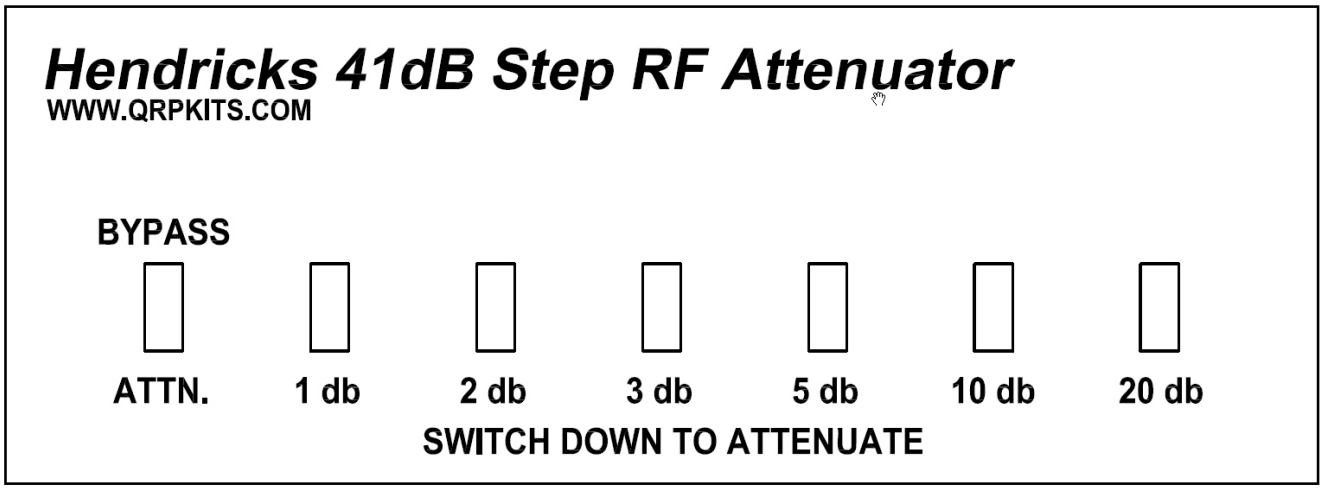
Turn the board over (switches down) and cut 2” long pieces of the supplied wire. Strip, tin, and solder to the I/O and Gnd. pads on the bottom of the board as shown. This completes the pcb assembly.

Testing:

Lets test the board before we proceed to the final assembly. If you put the resistors in the proper position, you should get similar values to our check we made with a digital ohm meter at the different switch settings. Hook up your ohm meter to either end of the attenuator I/O and Gnd. Place all the switches up into “Bypass” and the resistance should be infinite. Place the first switch into the “ATTN” position, then switch in and out of “Attenuate” each switch separately, to see if you get similar readings. The readings may not be exact, as the resistors are 5% tolerance, and your test lead resistance may be a little different than mine, but it will give you an idea if you inadvertently swapped a value.

1 dB - 456 ohms
2 dB - 235 ohms
3 dB - 153 ohms
5 dB - 107 ohms
10 dB - 64 ohms
20 dB - 57 ohms

Chassis preparation:



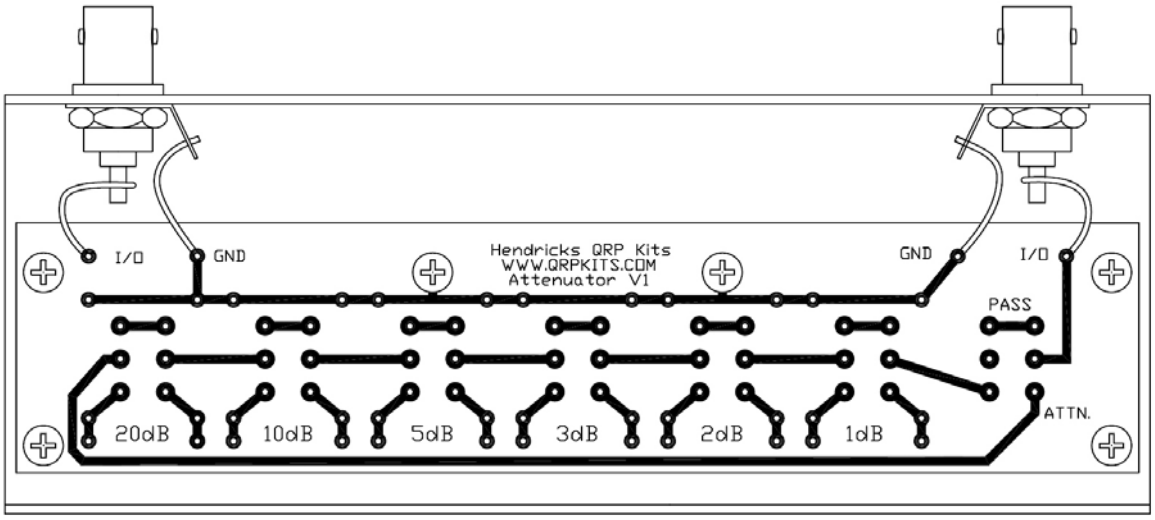
Thoroughly clean the surface of the panel to remove any oils or contamination. If you do not paint your case, we have found that moving the decals into position on a bare aluminum chassis is more difficult, due to the brushed surface, so we advise pre-coating the chassis with a light coating of the Krylon clear before applying the decals.

The decals are applied the same as model decals. Cut around each group of text you wish to apply. It doesn’t have to be perfect as the background film is transparent. Apply the decals before you mount anything to the chassis. Use the above picture to get the correct spacing around the holes

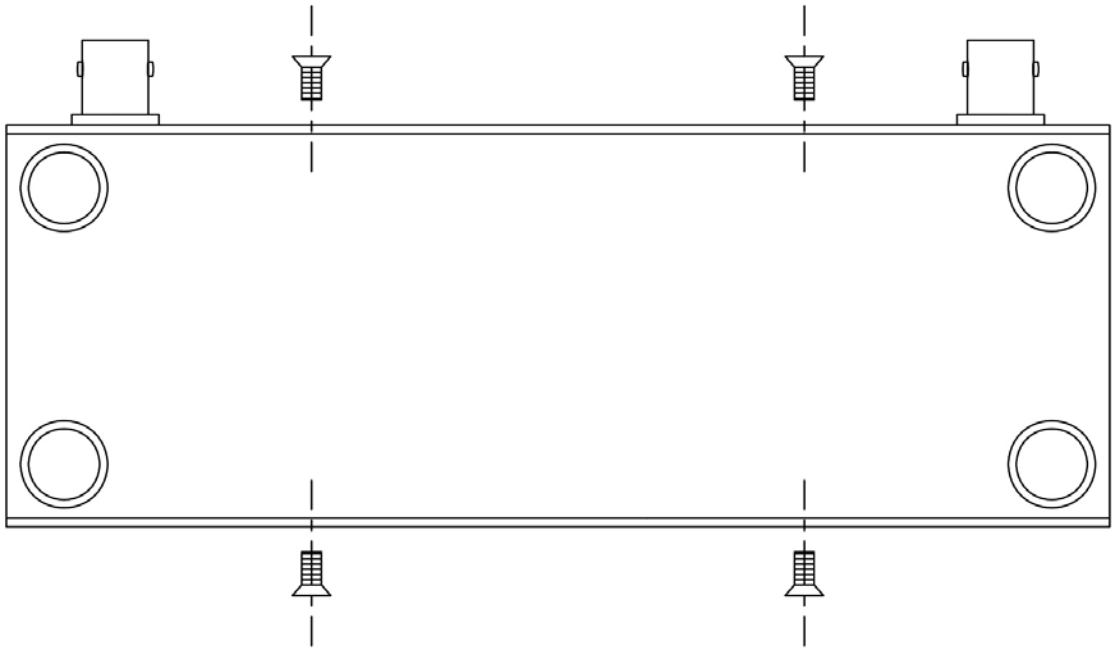
Trim around the decal. After trimming, place the decal in a bowl of lukewarm water, with a small drop of dish soap to reduce the surface tension, for 10-15 seconds. Using tweezers, handle carefully to avoid tearing. Start to slide the decal off to the side of the backing paper, and place the unsupported edge of the decal close to the final location. Hold the edge of the decal against the panel, with your finger, and slide the paper out from under the decal. You can slide the decal around to the right

position, as it will float slightly on the film of water. Use a knife point or something sharp to do this. When in position, hold the edge of the decal with your finger and gently squeegee excess water out from under the decal with a tissue or paper towel. Work from the center, to both sides. Remove any bubbles by blotting or wiping gently to the sides. Do this for each decal, and take your time. Allow to set overnight, or speed drying by placing near a fan for a few of hours. When dry, spray two **light** coats of matte finish, Krylon, clear to seal and protect the decals, and allow the spray to dry in between coats. All decals come with two complete sets, in case you mess one up.

- **Final Assembly:**



- Install the two BNC connectors with the ground tabs turned, as shown above.
- Install the finished pcb into the chassis cover as shown, using the six 4-40 philips pan head screws.
- Strip, tin, and solder the I/O and Gnd. wires as shown.



- Fit the bottom cover onto the chassis and secure with the four flat head 4-40 philips screws.
- Attach the four rubber feet on the bottom corners.

Using your Hendricks 41dB Step Rf Attenuator

The attenuator is bidirectional, either end can be an input or output. The attenuator can be taken completely out of the circuit, by switching to “Bypass”.

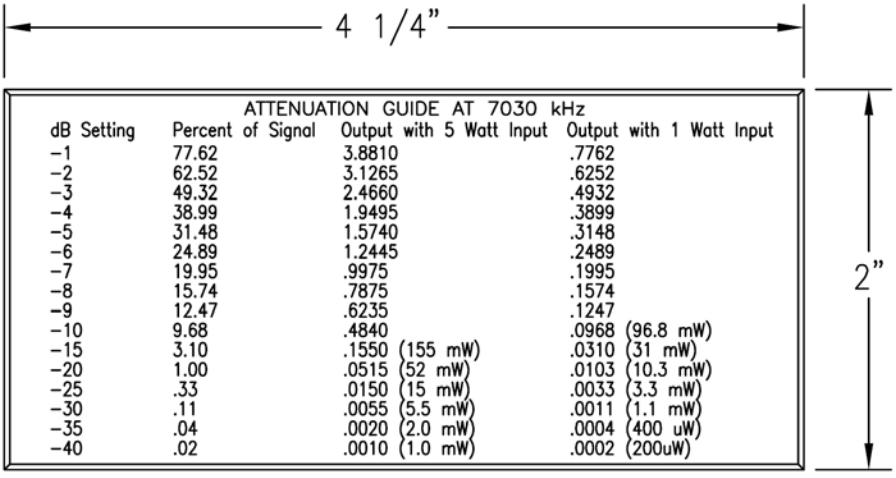
We designed this device to used on the HF bands up to 30MHz, our testing with an Agilent Network Analyzer PNA E8357A produced these values shown at 7030 kHz.

dB Setting	Percent of Signal	Output W with 5 Watt Input	Output W with 1 Watt Input
Bypass	99.77	4.9885	.9977
-1	77.62	3.8810	.7762
-2	62.52	3.1265	.6252
-3	49.32	2.4660	.4932
-4	38.99	1.9495	.3899
-5	31.48	1.5740	.3148
-6	24.89	1.2445	.2489
-7	19.95	.9975	.1995
-8	15.74	.7875	.1574
-9	12.47	.6235	.1247
-10	9.68	.4840	.0968 (96.8 mW)
-15	3.10	.1550 (155 mW)	.0310 (31.0 mW)
-20	1.03	.0515 (51.5 mW)	.0103 (10.3 mW)
-25	.33	.0150 (15.0 mW)	.0033 (3.3 mW)
-30	.11	.0055 (5.5 mW)	.0011 (1.1 mW)
-35	.04	.0020 (2.0 mW)	.0004 (400 uW)
-40	.02	.0010 (1.0 mW)	.0002 (200 uW)

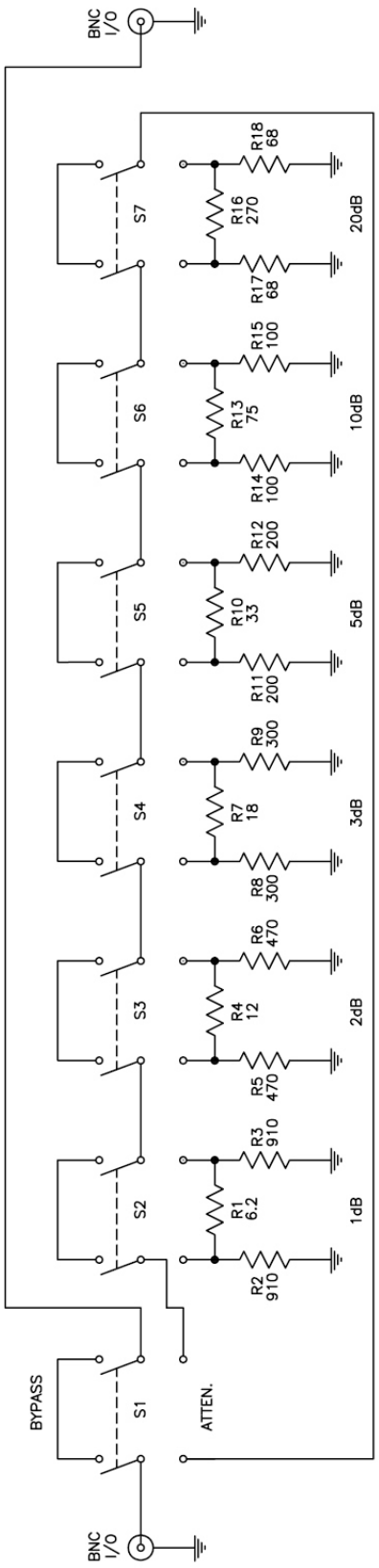
Theoretical dB to percent signal calculator can be found here:

http://www.lumonics.com/percent-to-dB-conversion-calculator.php

If you like, scale your printer to print this out to the dimensions shown, seal with some packaging tape, and apply it to the bottom of the chassis, with some two sided tape for future reference.



Schematic:



attenuator_assembly_101412.pdf

SHORTWAVE RECEIVER
10 kHz - 30 MHz

(2002)

KLIK HIER VOOR DE NEDERLANDSE VERSIE



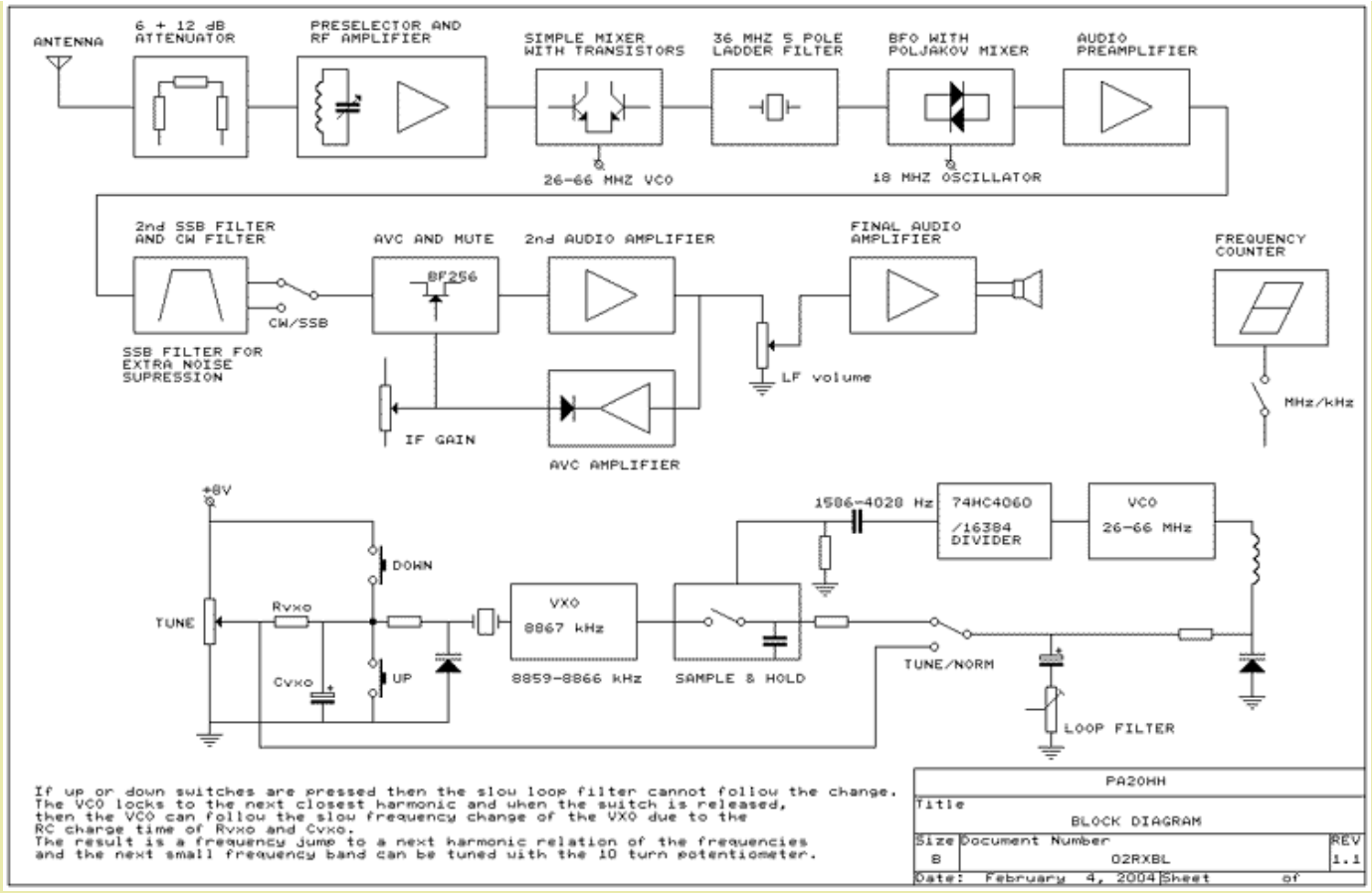
The simple shortwave receiver for CW and SSB.

SSB and CW receiver 10 kHz to 30 MHz
This receiver was made with use of the experiences of my first receiver. This new one has some improvements and modifications:

- It is much smaller, it is only 1/4 of the size of the old one.
- The VFO stabilisation circuit has been improved.
- The mixer and BFO have been simplified, simple readily available parts are used for it.
- The frequency counter with extra mixer for the BFO and VFO is replaced by one with programmable IF offset.

Enough ideas to justify the construction of a new receiver!

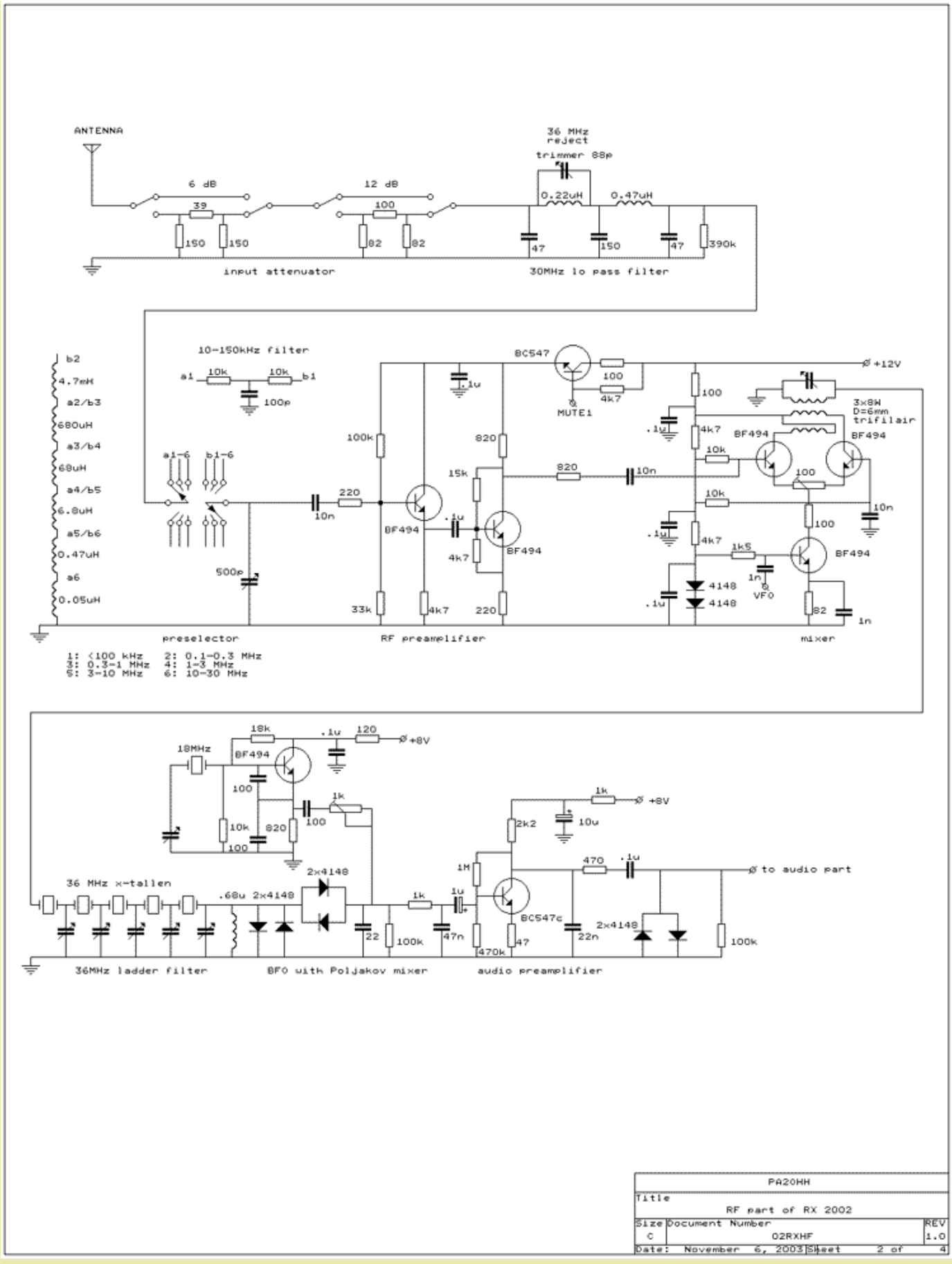
No AM reception
The receiver does not have AM reception. But if you want, you can receive AM in SSB mode. The advantage is that there is no distortion due to selective fading.
Speech sounds acceptable, just like SSB, music sounds like an old 78 rpm gramophone...



Block diagram.
big diagram

Description
The receiver has a 36 MHz IF with a 5 pole ladder filter and an almost drift-free VFO, it has Xtal stability, tuning is very comfortable.
The BFO frequency for a ladder filter should always be higher than the IF frequency, due to the asymmetric shape of that filter. To be able to listen to LSB signals below 10 MHz, the VFO runs from 36 - 10 MHz to 36 + 30 MHz. For LSB, the VFO frequency is below the IF frequency. So there is no USB LSB switch!
The AVC is derived from the audio.
At the input of the receiver is a RF attenuator and preselector.
For the frequency display, one 7 segment display is used. (see the page about a Simple frequency counter with one 7 segments led display).

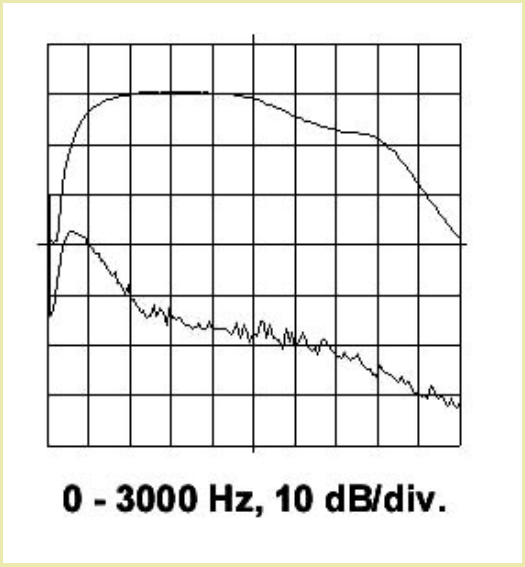
The RF part



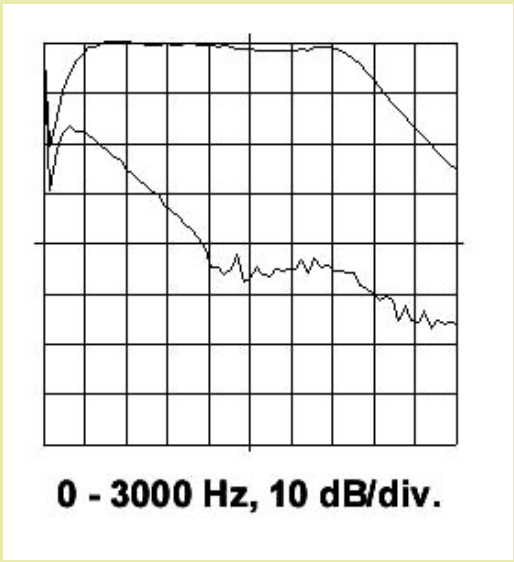
The RF part.
[big diagram]

Attenuator, preselector and RF preamplifier
The attenuator improves the reception considerably in the evening on the 40 and 30 meter band while the sensitivity is still good enough to receive weak stations. The low-pass filter suppresses the mirror frequencies and the 36 MHz IF frequency. A trimmer is added for extra suppression of 36 MHz signals received via the antenna.
Instead of broadband input filters, a tuned selective preselector is applied to improve the performance of the receiver considerably. The inductances are readily available parts and mounted directly on the bandswitch. For the band below 150 kHz there is a simple RC low pass filter.
The RF amplifier is certainly not a top performance transistor amplifier, but good enough due to the selective preselector. The first transistor is an impedance match, the second one gives some extra gain. The gain can be varied by changing the 220 ohm emitter resistor.

The mixer
The mixer is a balanced transistor mixer, not because that it is so good, but because I was curious to see if it is really as bad as they say. Well, it's performance is acceptable together with the preselector and input attenuator.
It is single balanced. A double balanced mixer will also attenuate 36 MHz signals from the antenna and noise on that frequency generated by the RF preamplifier. That will improve the sensitivity at 28 MHz. Another advantage of such mixers are a better buffering of the VFO signal. I had to add a resistor of 820 ohm between the RF preamplifier and the mixer to avoid that the VFO frequency changes when extremely strong signals (more than 0 dBm) were fed to the antenna input. My advice: Take a NE612 or even a SL6440 if you want to have a real good mixer, do not copy this one.



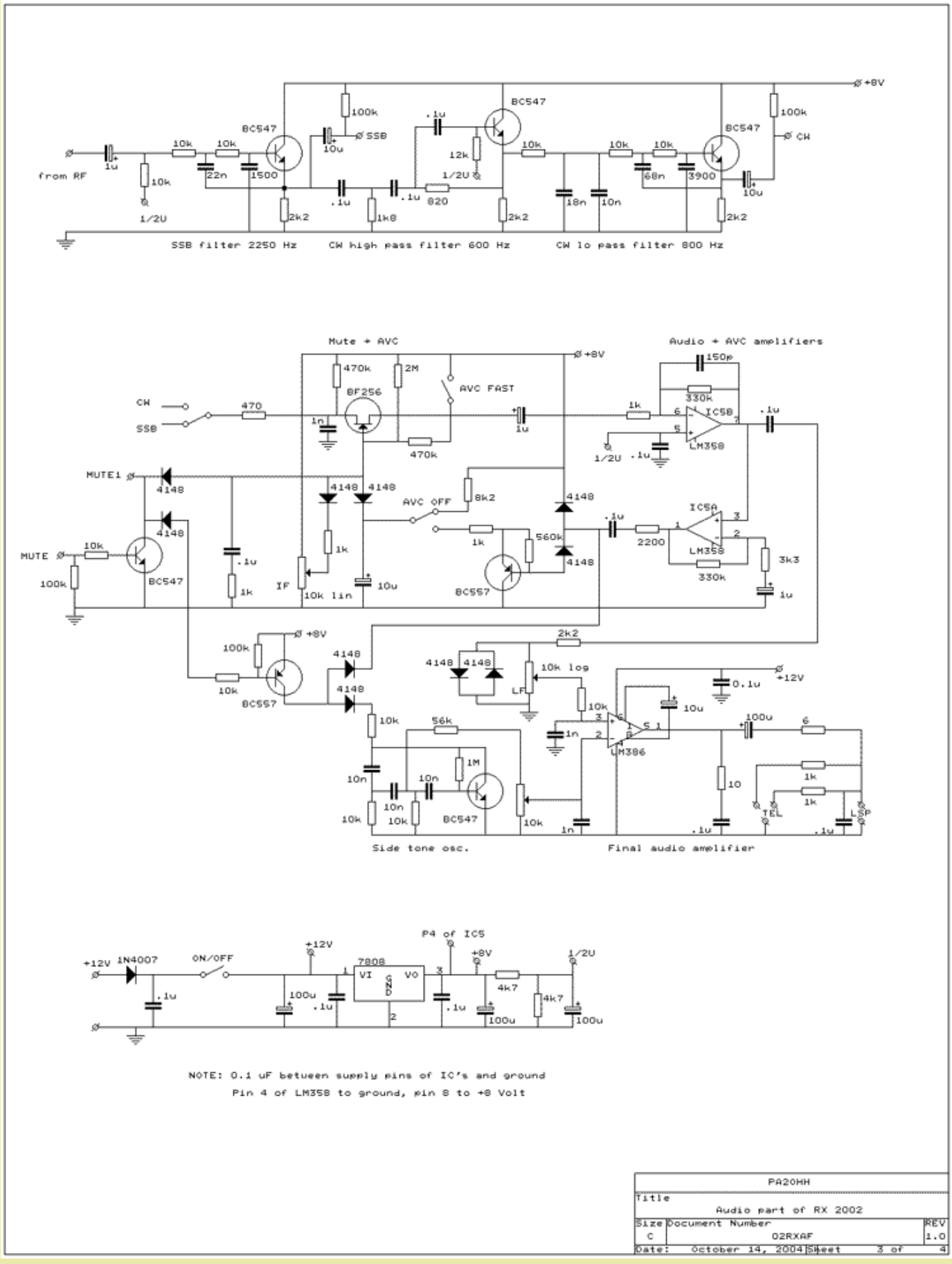
The 36 MHz ladder filter adjusted for maximum sideband suppression of 40 dB at 600 Hz. The upper trace is the filter curve, the lower trace the suppressed sideband.



The 36 MHz ladder filter adjusted for maximum flatness. Sideband suppression is less but still 25 dB at 600 Hz.

The IF and BFO
A 5 pole IF ladder filter (2 kHz wide) is followed by a Poljakov (or RA3AAE) mixer with two diodes. The BFO frequency for such a mixer is half it's working frequency (half the IF frequency: 18 MHz). The advantage is that it is easy to make a VXO for 18 MHz but not for 36 MHz as you need an overtone crystal for that frequency. It is not possible to make a good VXO with an overtone oscillator.
The IF gain control is not really an IF control as it is in the LF part of the receiver. But it has the same effect: Control the AVC voltage.

The AF part



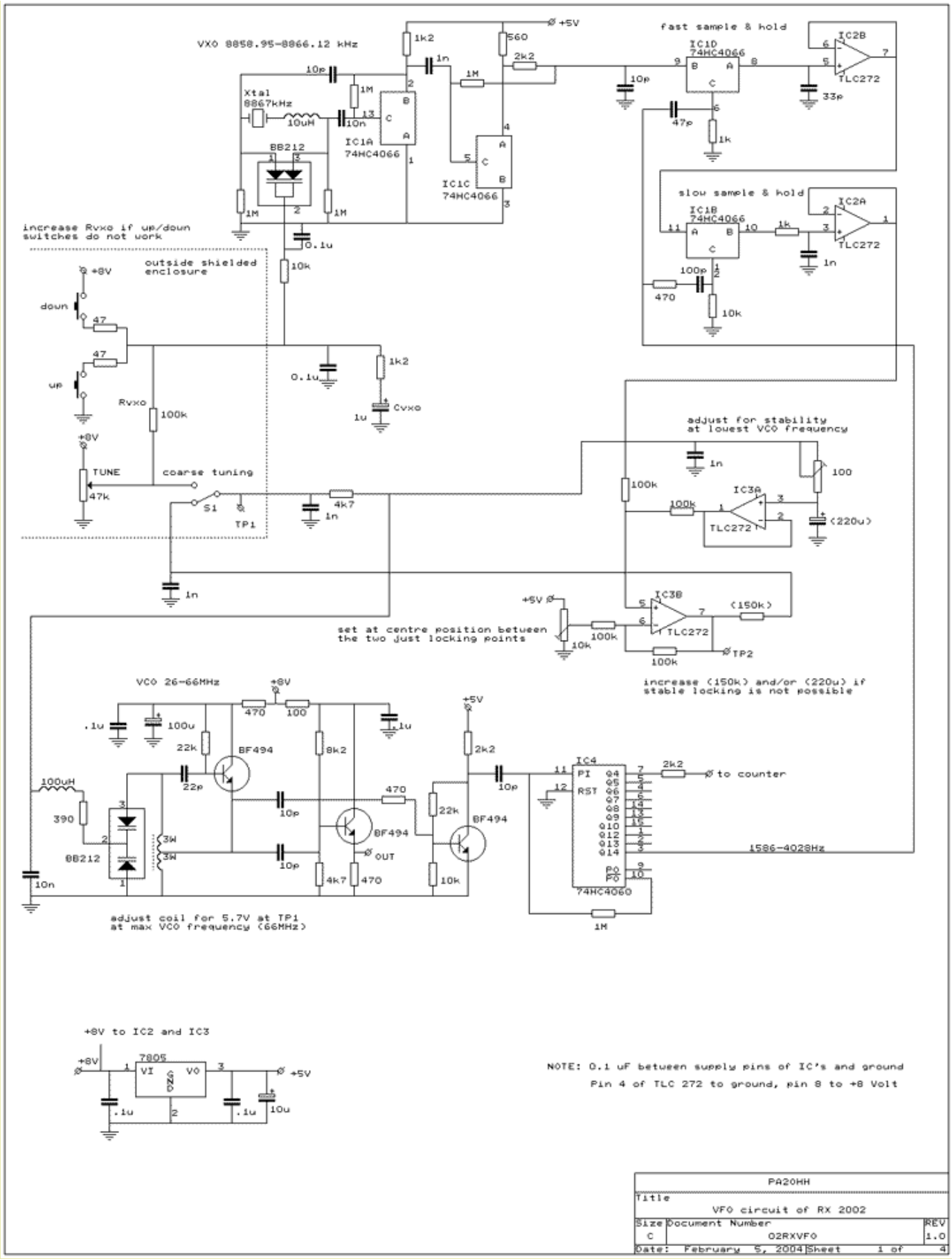
NOTE: 0.1 uF between supply pins of IC's and ground
Pin 4 of LM358 to ground, pin 8 to +8 Volt

PA2OHH		
Title: Audio part of RX 2002		
Size: C	Document Number: 02RXAF	REV: 1.0
Date: October 14, 2004	Sheet 3 of 4	

The audio part.
big diagram

The Audio part
At the input is a second SSB audio filter for extra selectivity and high frequency audio noise suppression. It is followed by a CW filter (600 Hz high pass and 800 Hz low pass).
The AVC is controlled by a fet in the LF part of the receiver. It is also used for mute during TX. Even a side tone oscillator is included, so that the receiver can be used with a transmitter.

The VFO



The VFO.
big diagram

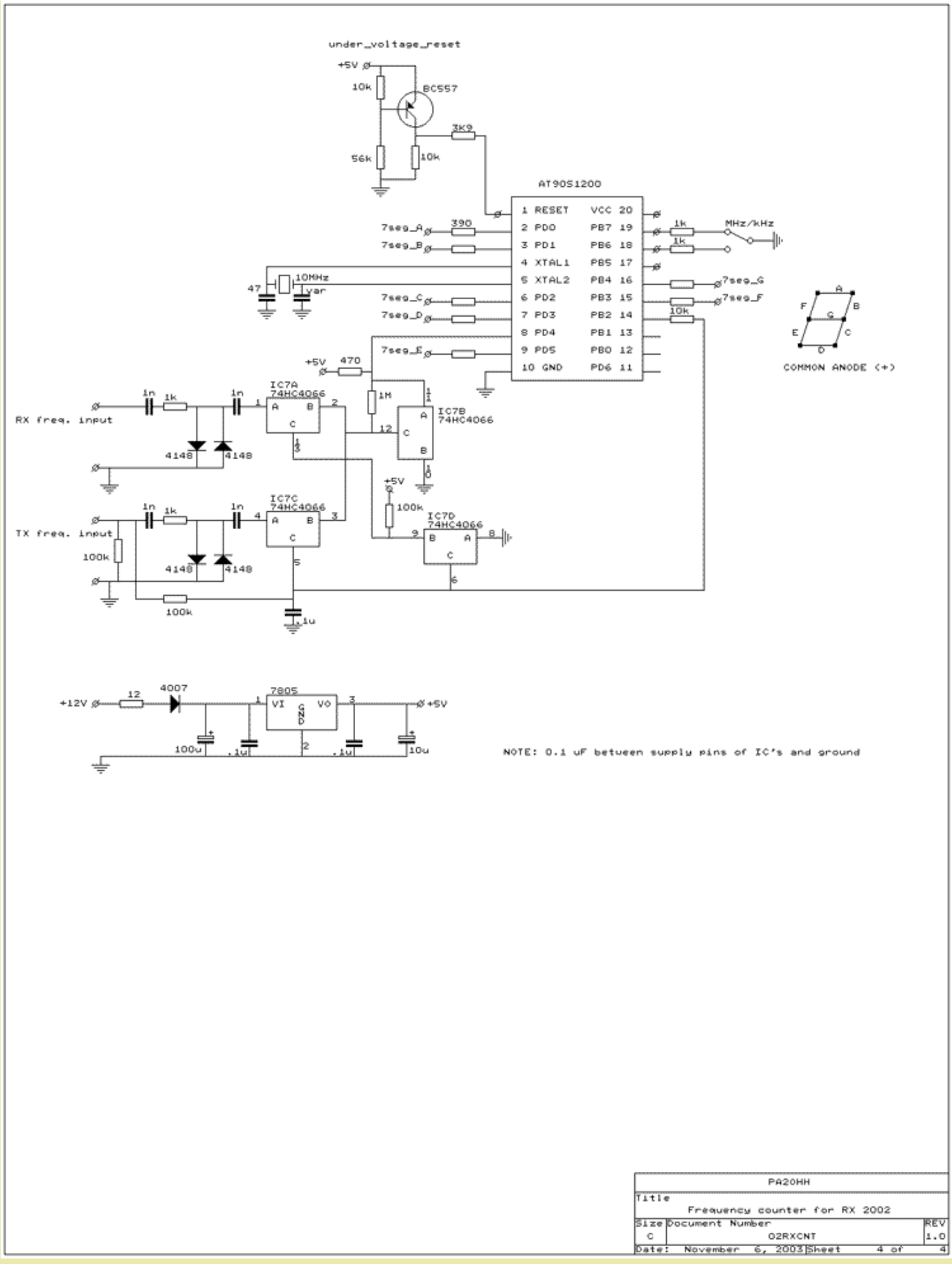
The VFO
The same type of VFO is used in the "MyTRX" transceiver.
Many small tuning ranges (23.6 kHz at 10 kHz and 52 kHz at 30 MHz) can be tuned by the 10 turn potmeter. Press the up/down switches to go to the nearest next small tuning range. For large frequency changes, set S1 to coarse tuning. Otherwise you have to press the up switch 1000 times to go from 10 kHz to 30 MHz!!
The system is based on a frequency locking system with a sampler with a VCO (Voltage Controlled Oscillator) and a VXO (Variable Xtal Oscillator). Harmonics of the (VCO/16384) are locked to the VXO. The VCO runs from 26 to 66 MHz and the VXO frequency is 8867 kHz. Frequency variation of the VXO is 7 kHz. If you want to calculate the tuning range, the formula is:

(VCO frequency) x (frequency variation of the VXO) / (VXO frequency)

So the range of the actual small frequency band that can be tuned by the 10 turn potentiometer is depending on the VCO frequency and the frequency variation of the VXO.
No ceramic resonator is used in the VXO as is in the "MyTRX" transceiver but a Xtal for better stability. Stability with a ceramic resonator is not sufficient for this design. In the MyTRX the VCO frequency is divided, giving better stability of the final frequency.
As the tuning range of the VXO is less than that with a ceramic resonator, the VCO frequency is divided by 16384 instead of 4096. The maximum frequency (here 4028 Hz) has to be less than the 7 kHz frequency variation of the VXO. Due to another division ratio, the loop filter component values are adjusted experimental (higher R and C). Adjustment of the loop potentiometers is possible with an oscilloscope at TP2, but you can do that even better with your ears. Tune to a strong carrier at a low VCO frequency and adjust the 100 ohm potentiometer by ear for the best distortion free audio tone. Even very small instabilities in the loop that are not noticed with the oscilloscope are heard by ear when tuning to a strong signal.

Up-down switches.
One important remark about that: The Up switch does only work properly if the VXO is tuned to a high frequency. For the lower VCO frequencies it works already when the VXO is tuned to its center frequency. And for the Down switch it is just the opposite.
Sometimes a (not very stable) locking occurs while there is an AC ripple on the loop (check with an oscilloscope on TP2). But you can solve this problem with some DC offset, adjust the 10k potentiometer a little to get this DC offset.

The Frequency counter



The Frequency Counter.

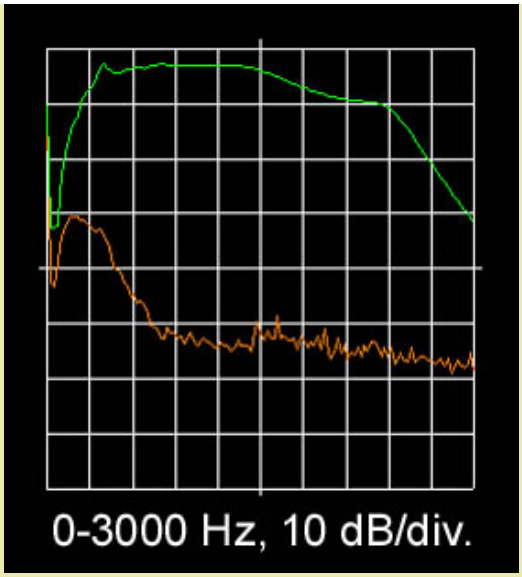
[big diagram]

The Frequency counter
Similar to that used in the "MyTRX" transceiver (see also the page about a Simple frequency counter with one 7 segments led display if you want to know how you can read the frequency while using only one display). There is an extra input to measure the frequency of the external transmitter. If a DC voltage is applied together with the RF signal, the counter measures the frequency of the transmitter. This DC signal is switched by the tune switch of the external transmitter.
The exact IF frequency is programmed by zero beating the VFO at 36 MHz (0 Hz reception frequency). This value is stored in the internal eeprom.

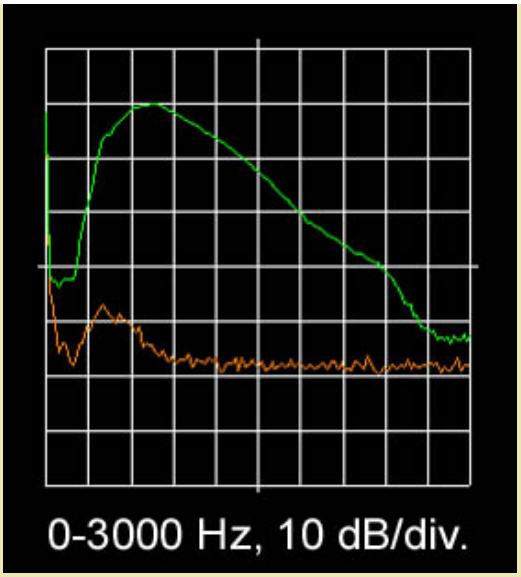


The start of the Receiver project.
Only some drawings and components. Will it ever work?

Notes for alignment
Adjust the trimmer of the 36 MHz reject filter for maximum attenuation of a 36 MHz signal when the receiver is tuned to the 10 meter band.
Adjust the 100 ohm potentiometer of the mixer for minimum noise for reception below 100 kHz.
Adjustment of the ladder filter is more complex. Input and output trimmers are tuned to maximum signal.
The four other trimmers (30-40 pF? I do not know) are set to 50 percent of their value. The AVC is switched off, the audio output from the loudspeaker is connected to the audio line input of the PC soundcard VIA A RESISTOR of 10k ohm.
An audio spectrum analyzer program is running on the PC.
While tuning around the 10 MHz clock signal of the frequency counter (or another carrier), see how the level varies when the tone height changes. Adjust the trimmers for best filter shape. At each audio frequency that has to be adjusted, find out which trimmer has most influence.
Well after two hours I had a shape that was a little optimized for CW and that had a quite good sideband suppression. It's performance is very acceptable!
Do not forget to adjust the BFO frequency of 18 MHz to the filter edge!



The SSB filter (green) and the suppressed sideband (orange).



The CW filter (green) and the suppressed sideband (orange).

Results

It works! Although not as good as an expensive commercial receiver, a lot of DX is heard on all amateur bands. Selectivity and sensitivity are good. Tuning is very comfortable. CW and SSB filter are okay. AVC works good.
As the mixer is not a very good one, I have to use the input attenuator in the evening at 40 and 30 meter. But also with the extra input attenuator, sensitivity is good enough to hear the atmospheric noise.
Even with 20 dB attenuation, the sensitivity on 30 and 40 meter is sufficient. The advantage is that the 3rd IP also increases with the attenuator value.
A lot of hours are already spend to listen to this receiver with pleasure. Even to AM transmissions! The receiver is stable and the CW filter sounds good, not too narrow. Operation is simple, no manual needed for all kinds of "hidden" controls.
Of course there was an error: the 56k and 10k resistors of the under-voltage circuit of the frequency counter were exchanged (diagram is correct, not the photo of the frequency counter). The result was that the EEprom values changed sometimes during switching off the receiver.

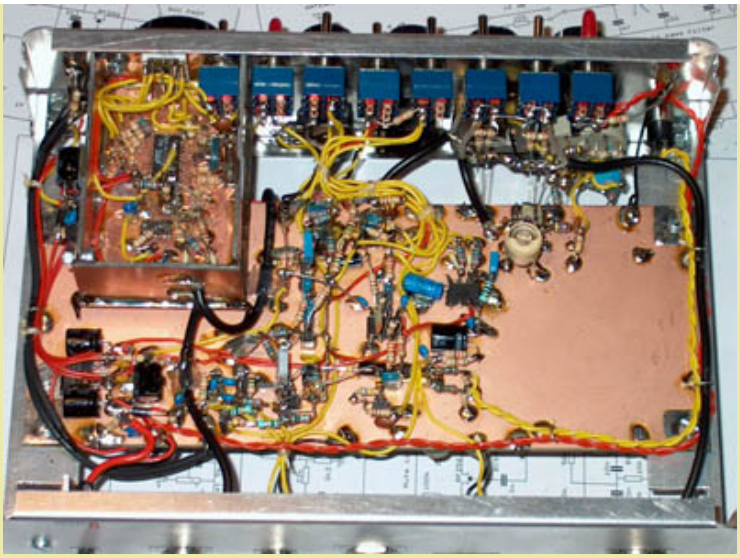
Frequency	3525 kHz	10125 kHz	28125 kHz
Sensitivity (SSB)	-130 dBm	-131 dBm	-123 dBm
3rd IP of whole receiver (-50 / -100 kHz)	-4.5 dBm	-10.5 dBm	+1.5 dBm

Supply current	100 to 150 mA

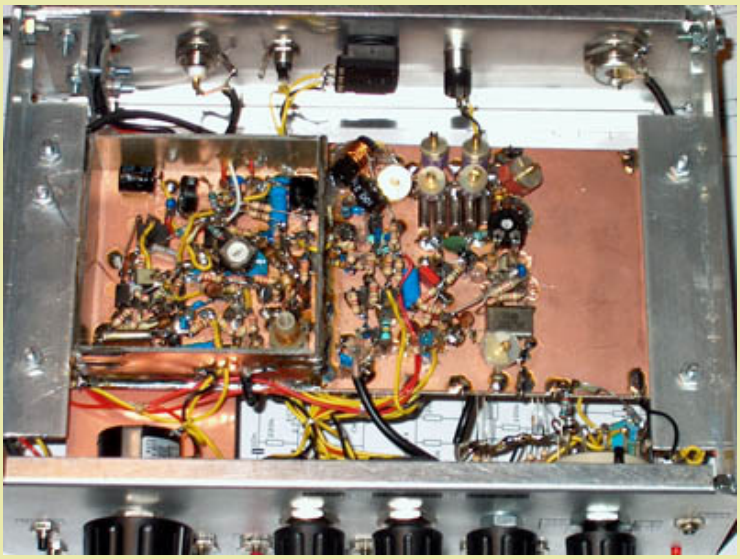
SOFTWARE FOR THE FREQUENCY COUNTER

"FREQRX02.ZIP" WITH "FREQRX02.ASM" TO PROGRAM THE FREQUENCY COUNTER

PHOTOGRAPHS OF THE RECEIVER CONSTRUCTION



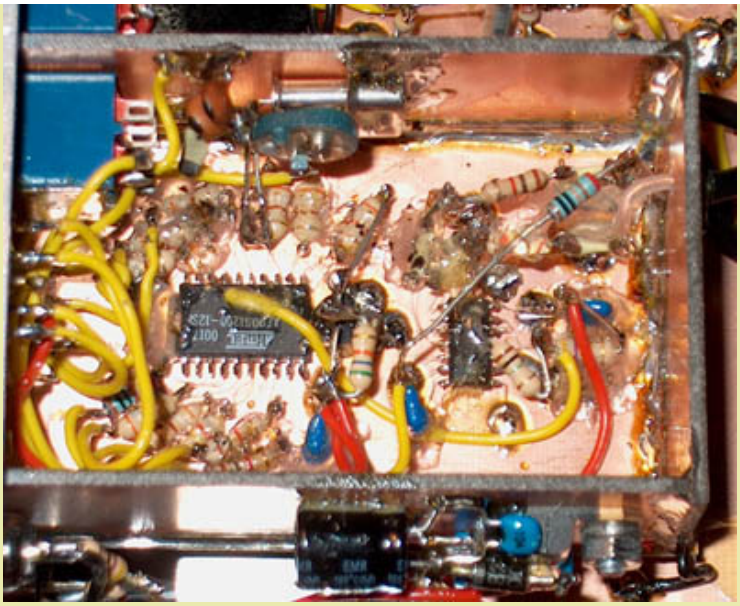
Top view of the interior of the receiver.



Bottom view of the interior of the receiver.



*RF preamplifier, mixer with trifilair coil on plastic rod (no ferrite!)
ladder filter, BFO with Poljakov (RA3AAE) mixer, LF preamplifier*



The frequency counter with SMD chips.
Thin wires are soldered to the pins of the chips before mounting them.
During soldering such a thin wire, the pin is isolated from the others by aluminium foil.
The SMD chips are glued on a piece of wood (from a match) on the PCB.
Pieces of a glue stick are used to fix the resistors etc. (melting them with the soldering iron).



Back side of the receiver

BACK TO INDEX PA2OHH

Tune Around!
SEARCH

CQ-Calling All Hams!
About Hamuniverse
Antenna Design
Antenna Safety!
Ask Elmer
About Batteries
Code Practice
Computer Help
Electronics
FCC Information
Ham Hints
Humor
Ham Radio News!
Post Reviews
Product Reviews
Ham Radio Videos!
HF & Shortwave
License Study
Links
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Reading Room
Repeater Basics
Repeater Builders
RFI Tips and Tricks
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Field Day Antenna!

by
Paul - AE5JU

(Updated 09-28-2012 with new mods info)

This past Field Day the club tried to use a folded loop that just didn't work. All contacts were made on my portable antenna. The club asked me to make something for them that would work on 75, 40, and 20 meters.

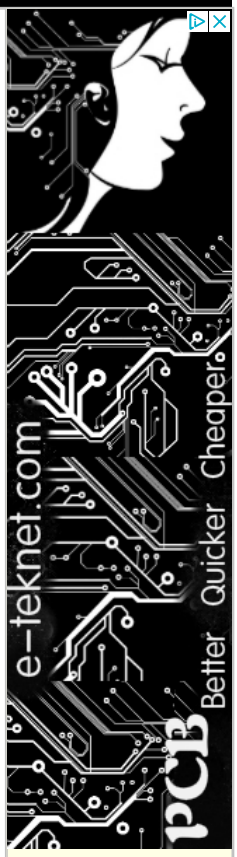
Let's skip right to the conclusion. I used this antenna to check in with my favorite regional net on 75 meters with my Icom IC-718 operating at 100 w SSB from a RBC-6 sealed lead acid ("gel cell") battery. Net control and assistant net controls reported that I sounded good, one giving a signal report of "10 over" from nearly 400 miles away.

This antenna will work on 40 and 20 meters without tuner, and with a little assist from a tuner will work on 17 and 15 meters, too.

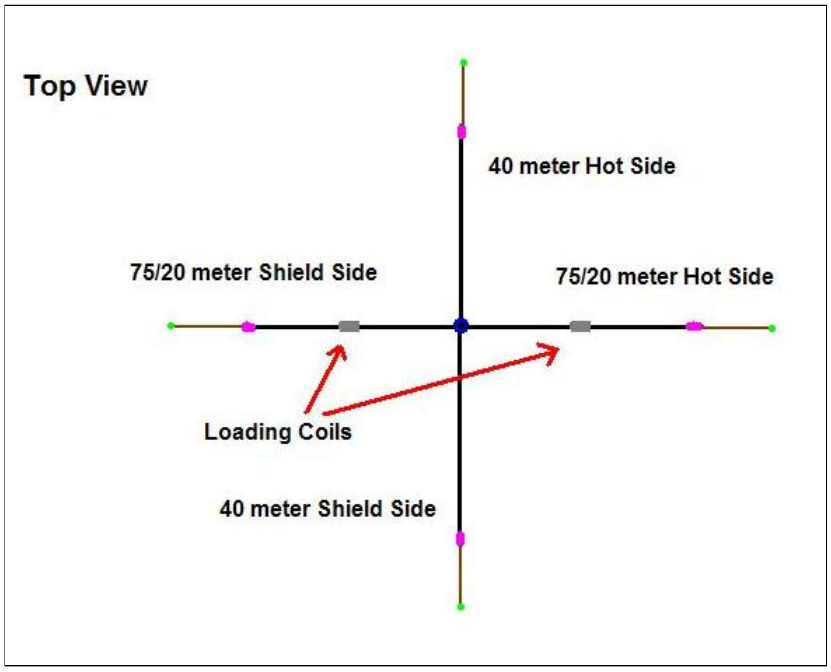
Here it is:

This is a Field Day / Portable / Emergency antenna I just finished trimming. An antenna analyzer made for easy trimming.









This is a multiband inverted V dipole. The club president and I had discussed bands that needed to be covered, so it was decided that 20 meters, 40 meters, and 75 meters were most important. Anything else is extra.

I made my calculations, cut my wire to length, etc. Left a few feet on the ends so that it could be let out.

The 4 legs are all about the same overall length. 40 meter legs go one way, and the 75/20 meter legs are at right angles. The wires double as the guys, with insulators out at the ends, and then 550 parachute cord going on out to tent stakes... or anything else you can find to tie to.

The 75/20 legs have coils in the middle of each leg. These are placed at about where the ends would be if the wires were cut for 20 meters only... traps or chokes. They also act as loading coils so that the overall length will work for 75 meters.

When dipoles are this low (about 22'), proximity to the ground lowers the antenna's impedance, which causes havoc with SWR. To counter this, like the Buddipole, the feedpoint is just off center, enough to bring up the impedance a bit closer to 50 ohms. The legs connected to the "hot side" of the coax are a little longer, and the coil on the 75/20 meters leg has a few more turns on the coil than calculated. The legs connected to the "shield side" of the coax are a little shorter, and the coil on that shield side 75/20 meters leg has a few fewer turns than calculated. This off center feed allowed for a minimum SWR of 1.3 to 1.4:1, which could not have been achieved otherwise.

Let's see if this theory works out...

20 meters resonated too high, needed lengthening.

Due to the way this antenna is made it was decided to lengthen the 20 meters segments first by unwinding a turn from the inner side of one coil. The coil former, 2" pvc pipe, has J-slots cut in each end so that wire may be let out or taken in.

Letting out one turn, lengthening that side by about 7", brought resonance down some, but not enough. Letting out one more turn on that same side resulted in these figures:

14.000 mhz 1.6
14.100 mhz 1.5
14.200 mhz 1.4

14.300 mhz 1.5
14.350 mhz 1.5

Next I tackled the 75 meters segments, which were tuned by cutting off the ends of the wire on these same segments. I took off about 2' on one end, and about 18" on the other to give:

3.900 mhz 2.3
3.910 mhz 1.7
3.920 mhz 1.4
3.925 mhz 1.4
3.930 mhz 1.5
3.935 mhz 1.6
3.943 mhz 2.0

There are some emergency nets on 3.925 - 3.935 mhz.

20 meters was rechecked, and remained unchanged.

40 meters was adjusted by removing about 10" from each end to give:

7.000 mhz 2.9
7.100 mhz 2.3
7.150 mhz 1.8
7.200 mhz 1.5
7.250 mhz 1.4
7.300 mhz 1.5

After these changes all three bands were checked again to make sure nothing else needed to be fine tuned.

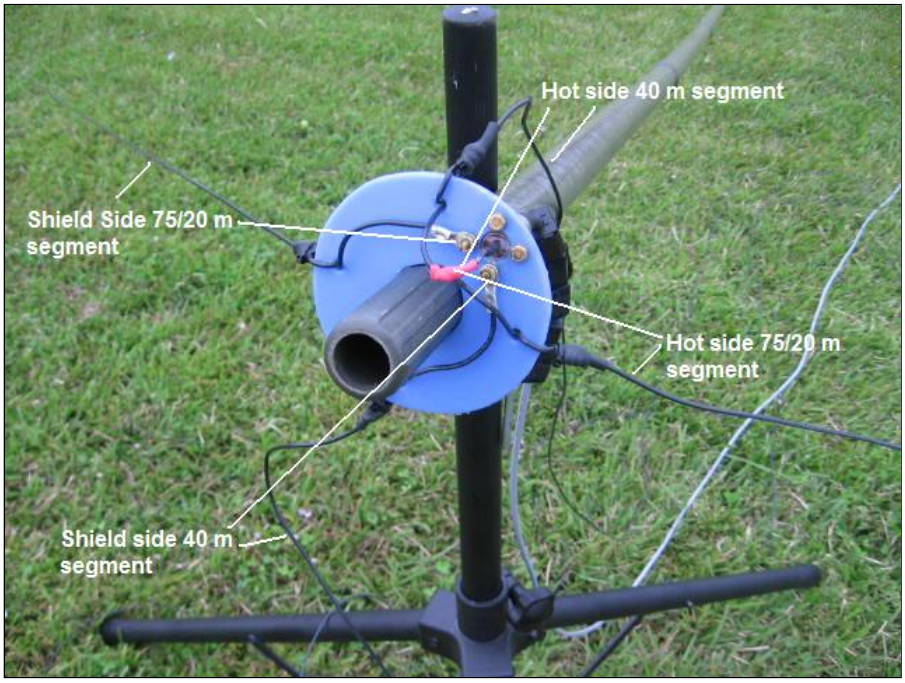
15 meters was found to be in the 3.5:1 to 3.0:1 range. A tuner can take care of that quite easily.



Loading coil. These coils are close wound on 2" ID pvc with 14 ga insulated wire. There are J slots on each end to allow adding or subtracting turns of wire.

Once the coil tuning was settled it was wrapped with 3M Electrical Tape.







Center insulator made from cheap Wallyworld kitchen cutting board.

100' of RG-8X coax was used, which is approximately 1/2 wavelength at 80 meters. Also, there are five Palomar Engineers FSB-1/4 ferrite snap on beads on the coax up by the feedpoint. These act as a "choke balun".



Base, PA Speaker tripod. The mast is 5 sections of fiberglass pole sections. These are military surplus camo net poles, an Ebay item.



End insulators shown above are ordinary ceramic dogbone type.
"550 Parachute Cord" extending out to tent stakes.

The recipe:

Wire used is 14 ga stranded insulated wire, the 500' roll for $25 from Home Depot.

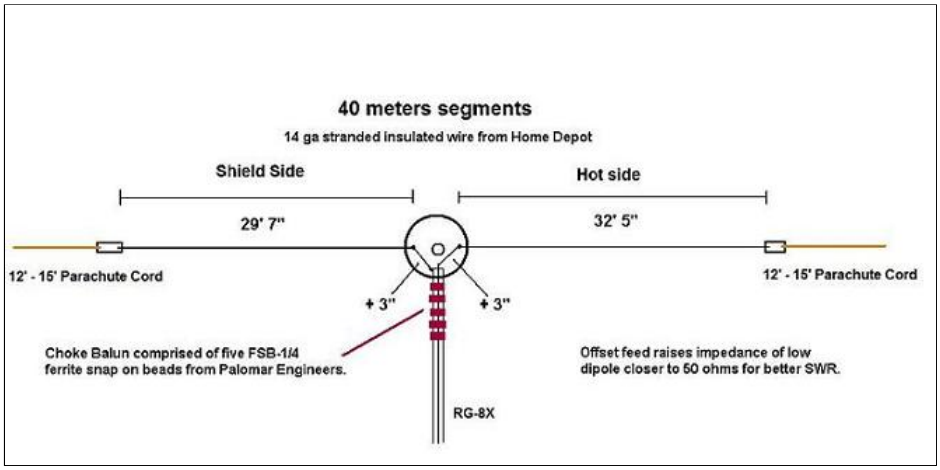
I had a lot of black parachute cord, but will buy some more orange for the end rope on this. Also, my plastic tent stakes are green. Difficult to see in the dark. I'm going to get some bright yellow tent stakes.

The center insulator is cut from a cheap plastic kitchen cutting board from Walmart. A half inch dia hole was drilled in it, and a SO-239 socket screwed to it. The top of the socket was sealed with Aleene's 7800 adhesive.

There is approximately 3" of wire from the socket to each of the four holes, or tie points for the wire legs.

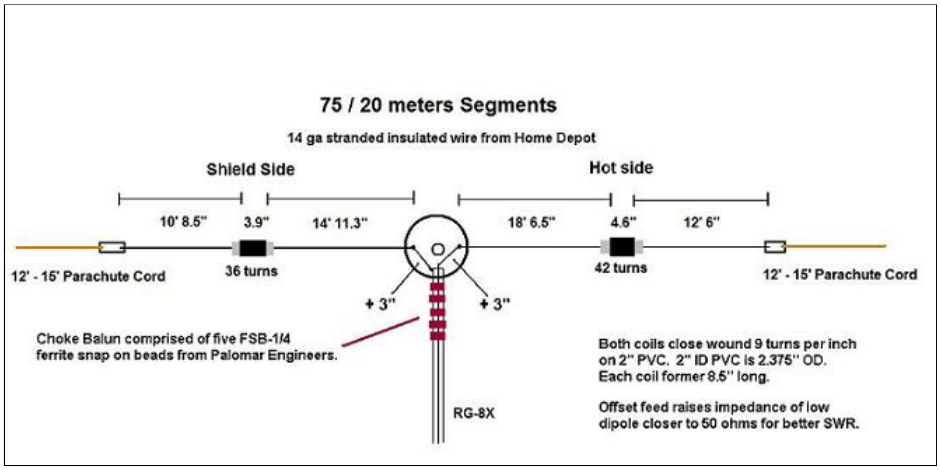
The two 40 meters segments go one way, and the two 75/20 meters segments are perpendicular to the 40 m.

40 meters segments:



Measurements are from the holes, or tie points on the center insulator out to the hole in the ceramic "dog bone" insulators on the ends.

75 and 20 meters segments:



This 75 / 20 meters section is wired parallel to the 40 meters section, only these legs are stretched out at right angles to the 40 meters legs.

Measurements for the inner 20 meters segments are from the tie points on the center insulator out to the first turn on the coils. The measurements for the outer wire segments are from the last turn of the coil on out to the hole in the ceramic "dog bone" insulators on the ends.

The coil formers are 2" ID PVC pipe, which is 2.375" OD. I have holes drilled in the pipe to secure the ends of the coils with ty-wraps. After tuning was deemed finished, the coils were wrapped with Scotch 3M electrical tape. I find Scotch electrical tape does not turn gummy and fall off with age. Good quality tape is worth the money. I made the coil formers with "J-slots" on the ends, to allow more turns to be taken off or added for tuning. Now that I have the final measurements that will not be necessary when making future copies of this antenna.

Due to the diameter of the 14 ga insulated wire, I was able to get right at 9 turns per inch, close wound, that is, turns touching each other. I used this 9 turns per inch figure in an online coil design calculator. This gave a nice repeatable build on the coils, and a length to diameter ratio of about 1.75:1, which is right in the middle of the suggested design ratios of 1.5:1 and 2:1.

Other notes:

There are five Palomar Engineers FSB-1/4 ferrite snap on beads placed on the RG-8X coax near the feedpoint. This forms a "choke balun" to stop RF on the shield. Similar snap on beads may be purchased from Ham City listed with the coax.

The apex of the antenna is at approximately 22'. This includes the tripod base and 5 fiberglass mast pieces. These are the common military surplus fiberglass camo net poles sold at hamfests and on eBay for use as antenna masts.

The only drawback of the coils is that the 75 meters bandwidth is narrower than if the antenna were full length. However, the antenna still covers the desired portion of the band with good SWR, and a little more using the tuner.
*** (see note at bottom of this post)**

But the use of coil loading and the overall length of this 75 meter antenna (appx 50% of full size) causes no noticeable drop in signal. I still got good signal reports from others I regularly talk to, so they know what I usually sound like with my full size dipole.

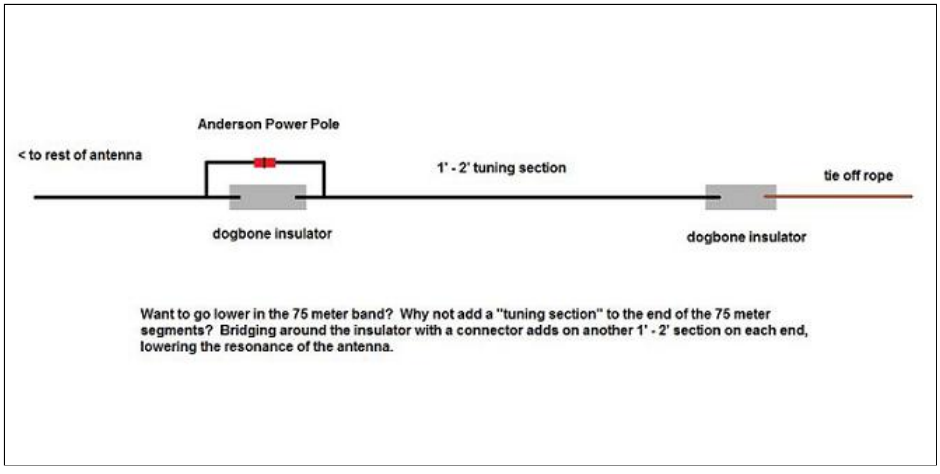
While this is not a permanent antenna for me, this might possibly help others fit 75 or 80 meters into a small yard.

One added note: While many say coax length does not matter, during initial testing with an analyzer I was getting good, consistent readings on 40 and 20 meters, but the 75 meters SWR readings were squirrely. Then it dawned on me... 50' of coax. Considering velocity factor, that is very close to 1/4 wavelength at 80 meters. The next time I tested it I used 100' of coax, and that works out to approximately 1/2 wavelength at 80 meters. SWR readings were consistent and stable.

Lesson learned: The old "conventional wisdom" to use 1/2 wavelength of coax got to be "conventional wisdom" for a good reason. I related this to one of our old club gurus and he just smiled and said, "Toljaso." Length does matter, so use 93' - 100' of coax with this antenna.

????-

*** So, a thought occurred to me... What if you do want to go lower in the 75 meter band? Why not put some sort of connector near the ends, down by the insulators? Then clip on some added pieces of wire, 1' long each, or 2' long each, and string them on past the insulator, perhaps securing them to the parachute cord end ropes with tie wraps? That would drop the resonant frequency to a lower portion of that band.**



Update!
New Additional Mods added to antenna base below! 09-28-2012



Added 1" split rings (like for car keys) and snap hooks

New Mod to Field Day Antenna done with Anderson Power Pole connectors



Measurements of wire lengths are now from the Powerpoles to the coils or end insulators.

Note that you may also download a pdf file of the antenna construction with mods here!

Erecting the Field Day / Emergency / Portable Antenna

Slip round insulator over top tenon of the top fiberglass mast piece.

Attach coax. Use 75' - 100' of RG-8X. Do not use 50', or it won't work on 75 m.

Clip the four wire elements to the appropriate rings on the center insulator. Observe colors and stripes on the connectors. The two plain wires will be opposite each other, with red to center, black to shield. The two coil loaded wires will be opposite each other with red-yellow to center, black-yellow to shield.

Spread out the wires fully, then bring in the ends of the ropes about 10'--12' and stake to ground. I suggest bright yellow tent stakes to help prevent tripping hazard.

Raise center mast vertically, placing new sections in one at a time from the bottom. Use a total of 5 sections of mast. Place on tripod.

Now go around and adjust stake position, wire/rope tension.

You may want to add ribbons of Caution Tape to prevent clothes-lining.

Will work 75 meters (resonant about 3.920 mhz), 40 m, 20 m, with little to no touch up from the tuner. Will work 17 m, 15 m, and 10 m with light touch up from tuner. Have not tried it on 6 m, but suspect it might work there, too. Let me know.

We have worked, from the Louisiana Gulf Coast, from coast to coast on Field Day, NY to CA, on 20 m and 15 m. Worked all over the Gulf Coast states, FL to TX on 40 m. At night I've done a regional net, LA, MS, TX, AR, OK, on 75 m at 100 w running off batteries, with good signal reports.

75 meters, due to the coil loading, is somewhat narrow. A tuner helps.

There you have it...Enjoy and have fun! AE5JU - Paul

Login to QRZ.COM for email address if you have questions!

Feedback:

Just wanted to pass a note along.

Had the opportunity to work the digital side of station K5R - Katrina / Rita 5th Anniversary. Fun and rewarding. To the point I had to bring all the gear I was going to use to the SELARC club station. I decided to build a copy of your field day antenna as described at http://www.hamuniverse.com/ae5jufielddayantenna.html It worked like a champ. I tuned it in the backyard and hoped it would work on the roof of the Ponchatoula Community Center. Once set up on the roof I checked the SWR with a MFJ antenna analyser. 20m was spot on. 40m was a bit off at 2.2 but good enough. Not worth the hassle of going back up there to tweak it. The tuner handled 30m so I could use that also.

Ended up with 60 QSOs from 28 states and 3 DX entities. Thanks for the antenna design.

K5HDE







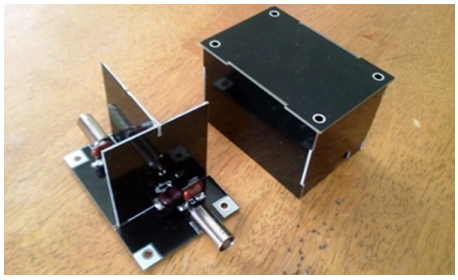


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4S-Low Pass Filter
Designed by David Cripe, NMØS

Copyright 2015
David Cripe NMØS
Four State QRP Group



Introduction

Thank you for purchasing the 4SLPF kit. These instructions are for both the 80M and 40M kits. The FCC requires all spurious emissions below 30Mc to be attenuated by 43 dB or more below the carrier, this includes QRP transmitters. A Pittsburg style PC Board, spiral pcb inductors, and a pcb case have been provided an easy building experience. Note that the kit doesn't include a balun for balanced line antennas. They are very easy to construct and your favorite search engine will find many examples.

Specifications

	Harmonic Attenuation dBc	
	2nd	3rd
80M Midpoint	-57	-59
40M Midpoint	-56	-59

Maximum Power Capability: Designed and tested for 100 wartts..
Impedance: 50 ohms in 50 ohms out.
Extremely low insertion loss, nearly zero.

Assembly:

1. Inventory the parts.

2. Break the 2 PC boards into 8 pieces. Sand any rough edges lightly.

3. Identify the 2 coil boards and place them into their notches on the main board. Hold them vertically and solder them to the PCB. Solder the connection near L2, C3, and the top of the coil boards, 5 connections total. DO NOT solder the connection near L1 at this time.

4. Assemble the cover base and the board with the 4SQRP Label. Use the L1/C1 side of the board assembled above to make sure you solder these 2 boards at a 90 degree right angle. Note: Snip the corner of the L2/C2 board so it won't interfere with the enclosure. See picture on the photo page for the size and location of the trim.

Assembly Continued

5. Now dry fit the remaining 3 boards to the cover base assembly. Make sure the notches are pointing away from the cover board. Place a couple of rubber bands around the loose assembly and make sure everything is square before soldering. (Reflow the joint created in step 4 if needed.)

6. Now solder all connections on the cover assembly

7. Solder the remaining connection near L1/C1 at this time.

8. Solder in the capacitors, checking their values against the parts list, and matching them to the correct position on the pc board. NOTE: C1 on the L1 board should have been marked C2.

a) C4 and C2 (labeled C1 on some boards) are standard thru-hole parts mounted on the vertical coil boards

b) C1, C3, and C5 are mounted Pittsburg style on the main board. You will need to bend the leads before soldering these capacitors. *Bend them in a "W" shape to facilitate installation, see picture to the right.*



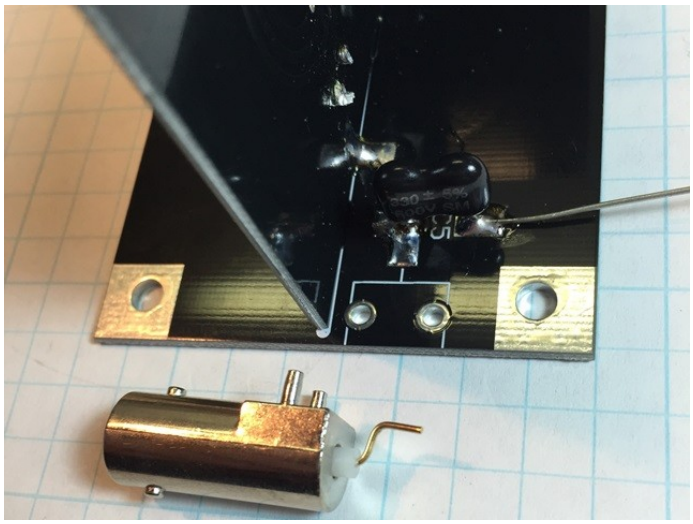
Bend capacitor leads thusly for easy soldering and trimming. This is the "Pittsburg Bend" for Silver Mica caps.

c) The center lead on J1 & J2 will also need to be formed before mounting. See picture on photopage.

9. Screw the stand-offs to the main PCB using 4 of the screws. Screw the cover to the main PCB using the remaining 4 screws.

That's it! Check off each part as it's installed, and refer to the pictures below and on the photp page. for more detail as you build. This is an easy build, the coil boards can be positioned by hand if desired, and the enclosure sides can be held together with rubber bands or tape for soldering, nothing is tricky or critical.

Assembly Continued



BNC Bent for soldering

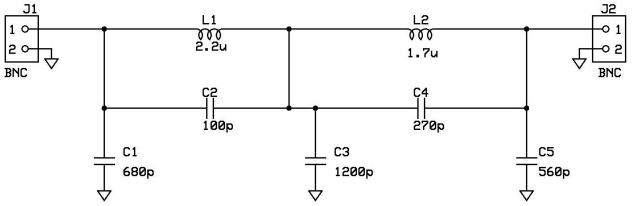


Ready for the enclosure.

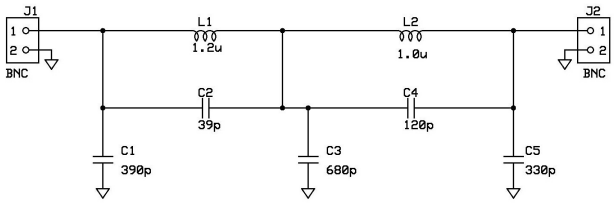
See the Photo Page for more assembly pictures.

Click the link .

Schematics and Bill of Materials



80 Meter Schematic



40 Meter Schematic

Qty	Component	80M	40M	Note
1	C1	680p	390p	Silver Mica
1	C2	100p	39p	Silver Mica
1	C3	1200p	680p	Silver Mica
1	C4	270p	120p	Silver Mica
1	C5	560p	330p	Silver Mica
1	L1	2.2u	1.2u	Spiral PCB Inductor
1	L2	1.7	1.0u	Spiral PCB Inductor
2	J1, J2	BNC	BNC	Coax Connectors
2	PCB Inductors	80M Ver.	40M Ver.	Verify your kit

For these components both kits are the same

1	Enclosure - top, sides, and Pittsburg PCB
4	3" 6-32 Standoffs
8	6-32 screws

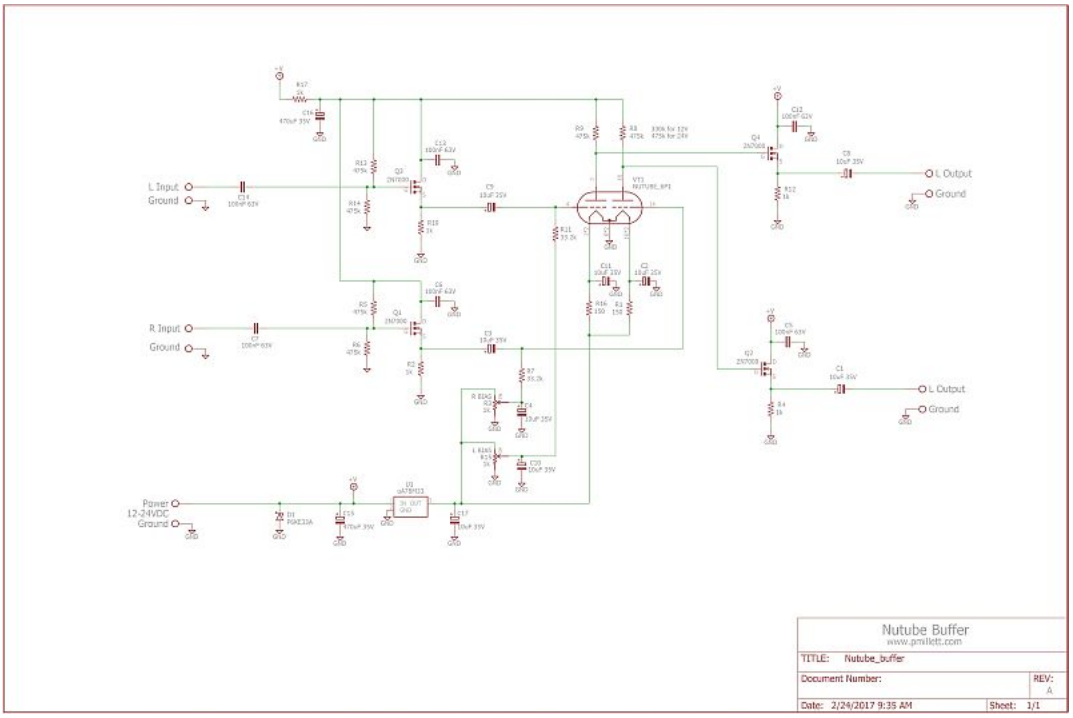
DIY Audio Home

Korg Nutube 6P1 buffer

NEW - Oscillation of input buffer

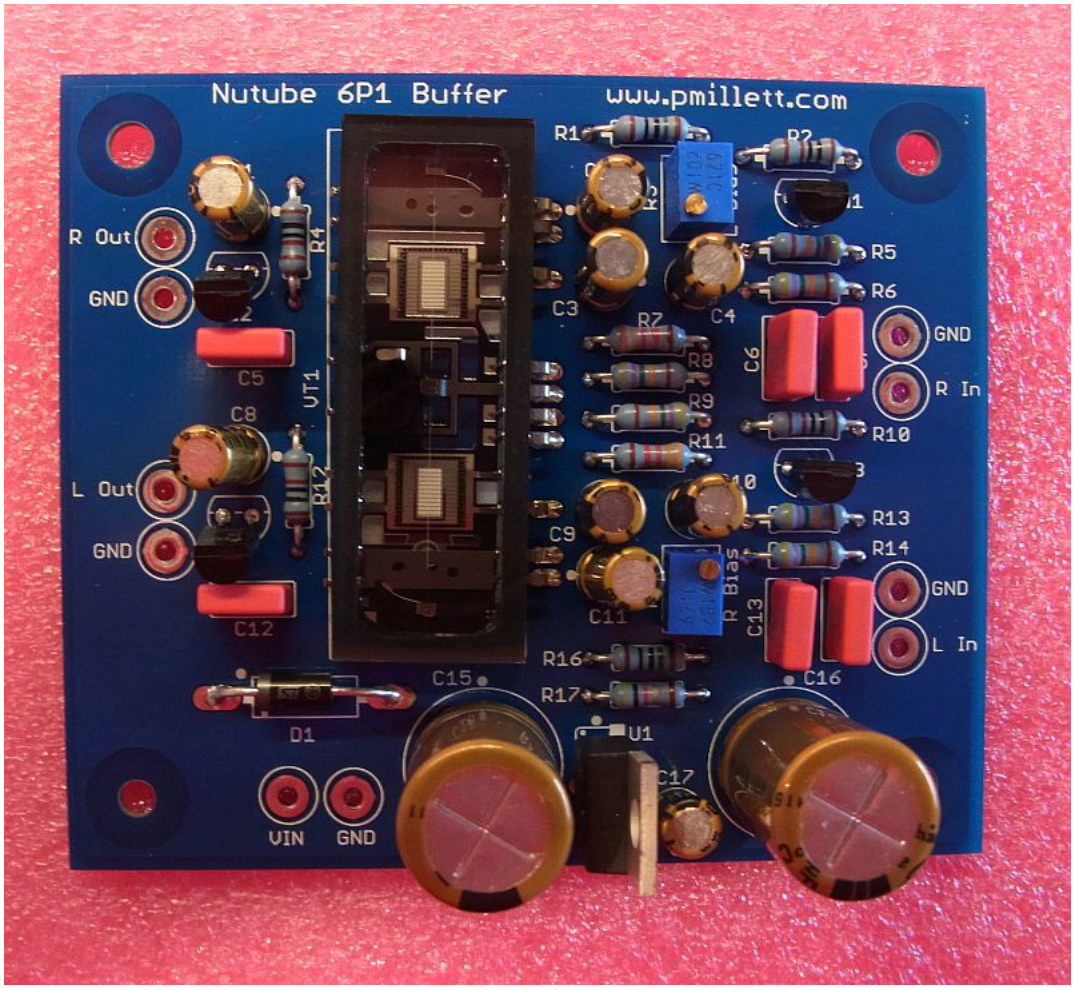
Under some conditions, the 2N7000 input buffers (Q1 and Q3) may cause high frequency oscillation. There are two solutions: Insert a gate stopper resistor of around 1k in series with the MOSFET gate, or replace the 2N7000 FETs with 2N3904 NPN transistors. If you use 2N3904 then you should also change R2 and R10 to 10k.

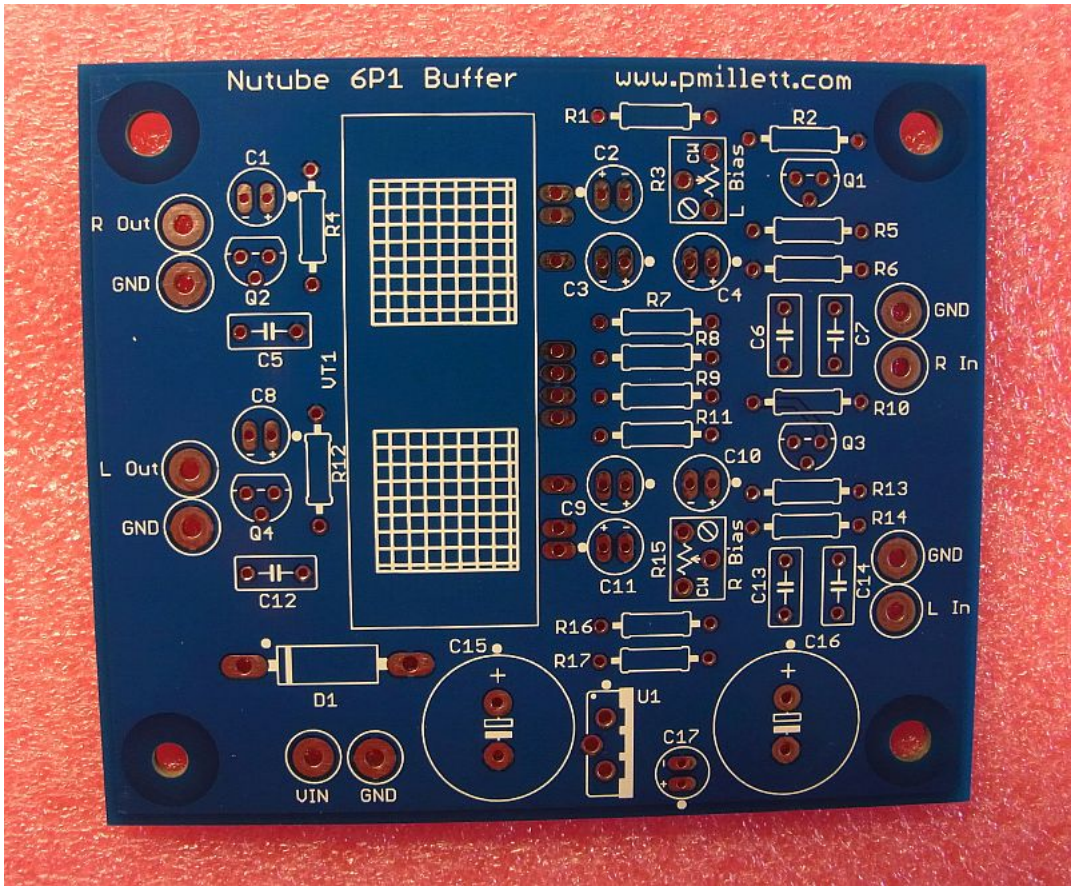
I have had some requests for a simple buffer PCB using the Korg Nutube 6P1. So, here it is...

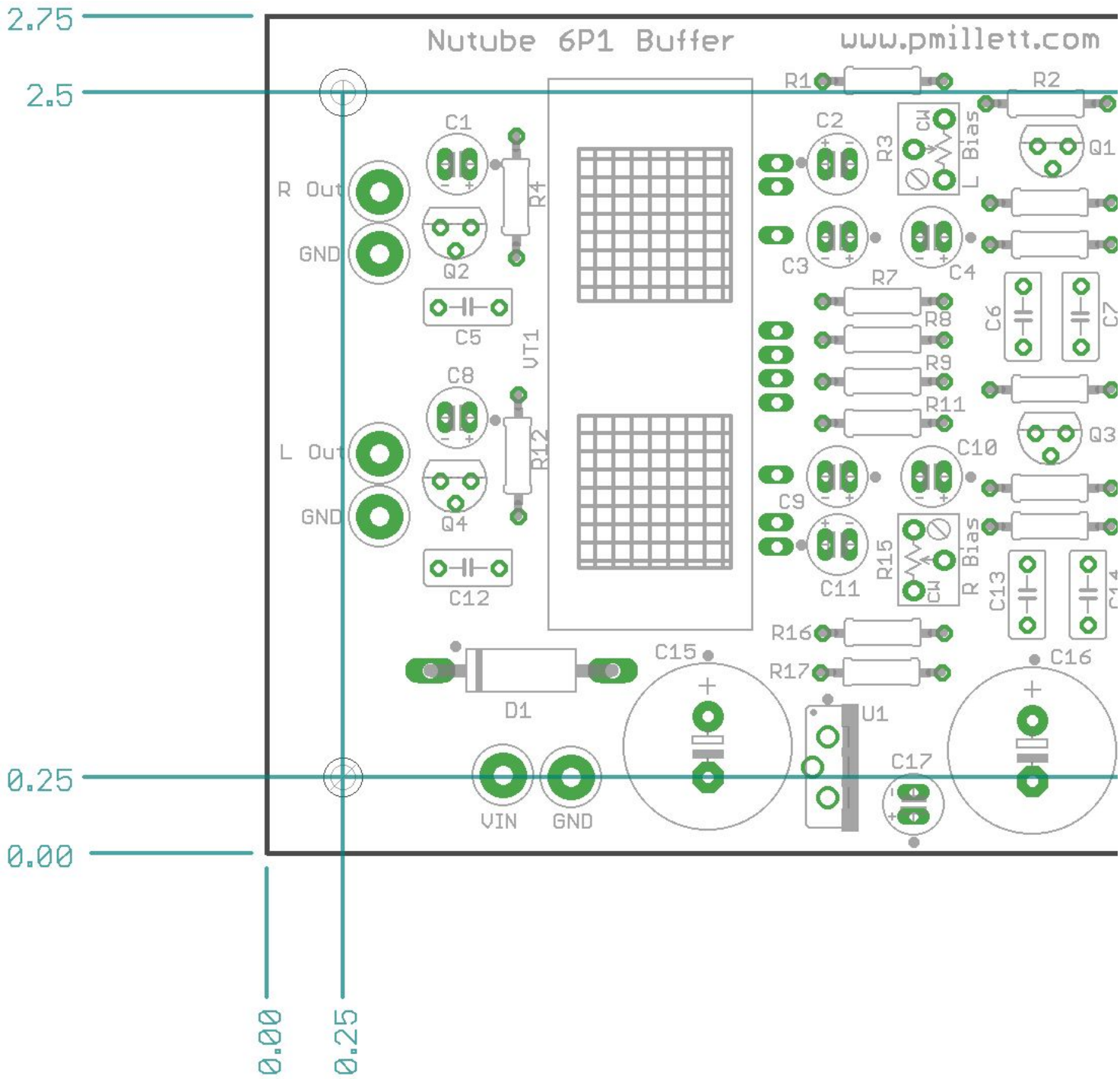


Here is the schematic in PDF form, and the parts list (BOM) in PDF or XLS. Also, I made a Mouser BOM with all the parts (the access ID is bbee51d8dc if the link doesn't work) . The total BOM cost is $66.10 from Mouser, and $50 for the PCB plus Nutube 6P1 from my eBay store.

This board uses each half of the 6P1 (it is a dual triode device) separately, to give you a stereo line amplifier.


Nutube 6P1 Buffer
www.pmillett.com
R Out
GND
L Out
GND
VIN
GND
GND
R In
GND
L In
R Bias
R Bias
VT1
D1
U1


Nutube 6P1 Buffer
www.pmillett.com
R Out
GND
L Out
GND
VIN
GND
GND
R In
GND
L In
L Bias
R Bias
VT1
D1
U1
Q1
Q2
Q3
Q4



The idea here is to implement a simple single stage amplifier using the Nutube, so people can evaluate it in an audio system.

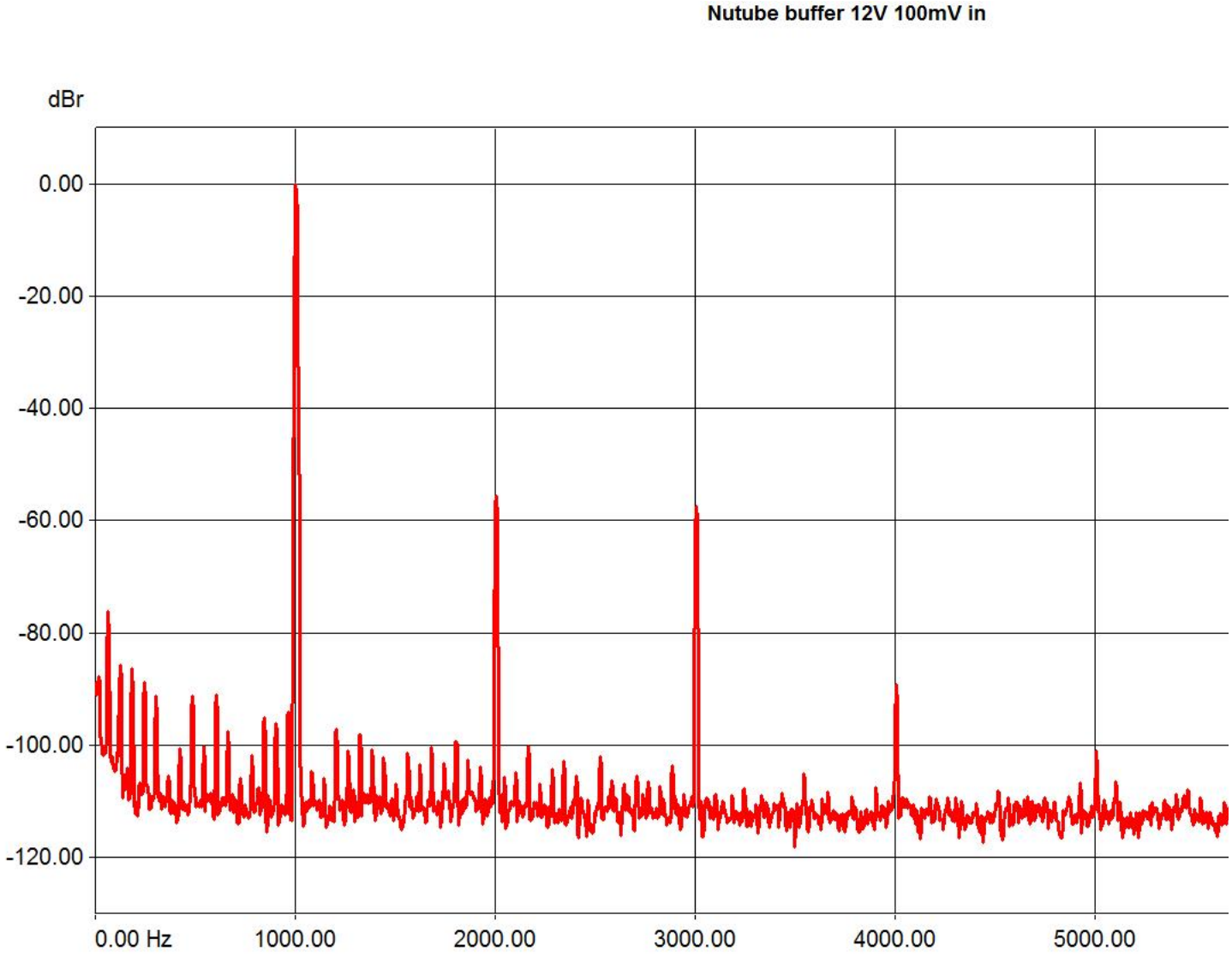
You can get more details about the Nutube at www.nutube.us. I'll be selling the PCB, along with one of the Korg 6P1 Nutube devices, on my eBay store.

Most interest in using this device is to provide "signal processing" - specifically, to make a solid-state amplifier sound more like a big single-ended tube amplifier. I have built a Nutube / class-D hybrid that did exactly that... it really did measure and sound a lot like a big SE tube amp. Whether that's your "cup of tea" or not I leave up to you...

The board runs from a power supply of 12V DC typically. It will work anywhere from about 5V up to 30V using the components specified.

Since the 6P1 is usually operated in class A2, with some grid current, the board has MOSFET followers to drive the grids. Since the 6P1 has relatively high plate resistance, I also put MOSFET followers at the outputs. If you are driving something that has high input impedance (> 100k or so), you can not populate the output buffers and jumper around them if you want.

Powered from 12V, the buffer has a gain of about 6x. You can adjust the bias to change the distortion characteristics - minimum THD with 100mV in (and ~600mV out) is about 0.2%. An FFT under these conditions shows typical single-ended triode characteristics. Note that if you skew the bias you can change the relative proportions of even and off harmonics; this was taken with the total distortion minimized.


Nutube buffer 12V 100mV in
dBr
0.00
-20.00
-40.00
-60.00
-80.00
-100.00
-120.00
0.00 Hz
1000.00
2000.00
3000.00
4000.00
5000.00

HOMEBREW AMATEUR EQUIPMENT :

7 Watt QRP AM/CW Transmitter

Collected from the Amateur
Magazine 'QSP'
Circuit by: K.R.Vasnthakumar,
VU2 VWN , Kalapurakkal,
Thuruthipuram,
Moothakunnam - 683 516

The whole set up consists of a 7 MHz VFO with buffer, an RF Power amplifier section consisting of 3 transistors and its power supply, a TBA 810 Modulator with a single transistor Pre-amplifier and its powr. supply .

FIG 1 : Variable Frequency Oscillator :

The VFO consists of 2 FETs (BEL BFW 10) . The first FET in the Oscillator with the fundamental frequency of 7 MHz . The second stage- is a Class-A Buffer. The VFO draws 4 mA from a 6 Volt battery

The container is a slightly large Eliminator box . An ordinary 'L' Board. can be used to assemble the circuit .

The Oscillator uses a Colpitte's Configuration . The voltage - feedback for sustaining oscillation is getting from the capaciotr divider, network . These oscillations are coupled to the Buffer gate through a 10 pF Capacitor .

The buffer is operating as Class-A . The necessary reverse bias at the gate is developed across the source of buffer . The - amplified signal from the buffer is coupled to the power Amplifier section through a 100 pF capacitor.

Remarks : The capacitor should be Loww Loss Type ; So 'STYROFLEX' is preffered rather than Tubular Ceramic . Otherwise the oscillator may refuse to oscillate.

IF THE OSCILLATOR REFUSE TO OSCILLATE USE AN RFC INSTEAD OF THE 1 K2 RESISTOR IN THE SOURCE OF 'OSCILLATOR'. To make this RFC , wind 150 turns of SWG 36 enamelled wire on a 100 K (or any other high Value) 1/2 Watt resistor and solder the ends to the resistor leads . Also you can try increasing the supply voltage to 9 Volt. The 'Oscillator Coil' should away from the metal enclosure .

Fig 2: RF Power Amplifier and its Power supply :

The Radio Frequency Power Amplifier consists of three(3)stages : (1) The Pre-Amplifier , (2) The Driver , and the (3) final stage ; These consist of BC148B in Class A mood , an SK 100 in Class and the final a BD 139 in Class C respectively .

P.T.O.

- The pre-amplifier is an R-C Coupled one while the driver collector-load is an RFC damped with 1 K resistor in order to suppress unwanted Self-Oscillation . The base of BD 139 is directly coupled to the collector of SK 100 . The Tank Coil is placed in the collector of BD139. THE TAPPING ON THE coil ARE CRITICAL . The Antenna Connector is an ordinary Mike -connector , so two 0.1 mFd. capacitor are used for-isolating the DC. from the mike-connector .

The power amplifier pwr. supply is a full wave centre tapped one. The power transistor is with a 24-0-24 V,@ 1 Amp. secondary . Since the load current is only around 200 mAmp. , the rectified voltage will-be much higher than the rated voltage . The voltage drop across the winding will be in significant . So the output voltage from the power - supply will be around 35 Volts . A bridge rectifier circuit is not-- recommended because it causes hum in the signal .

Fig. 3 : The Modulator Section :

The modulator is a TBA 810 IC Audio Amplifier with a single transistor Pre-Amplifier. The TBA is operating on 11 VDC supply from-an eliminator and is using standard circuitry . The audio pre-amp. is a CIL 464 transistor . The 0.01 mFd. capacitor from the base of CIL464-to the ground is an RF bypass capacitor . The RF may induce in the pre--amp. while transmitting . Lower values can be used for this purpose . a 100 ohm 1/2 watt resistor is connected accross the output of the modulator . When the Tx (Transmitter) is in AM position this 100 Ohm will come in series with the emitter of the SK100 .

The modulator power supply is a half-wave rectifier . The Condenser Mike shown in fig 3 is having three connections but two connections Mike can also be used equelly well .

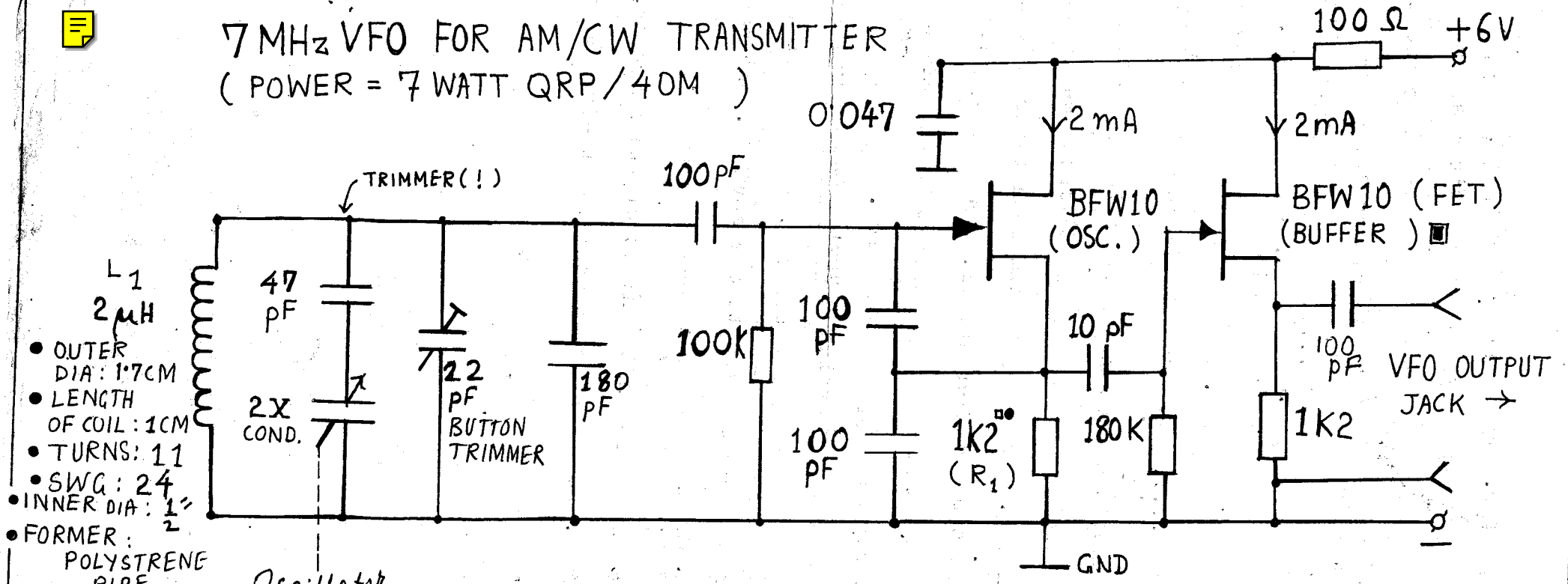
Use an external Voltage stabilizer (from your TV set !) in the RF power supply section .

SANDEEP BARUAH 3.7.86

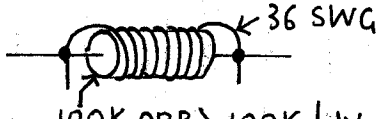
FIG 1

7 MHz VFO FOR AM/CW TRANSMITTER

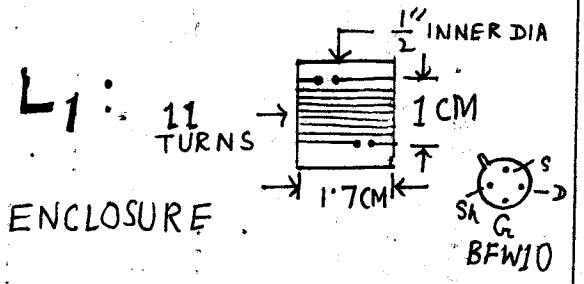
(POWER = 7 WATT QRP / 40M)



- ALL CAPACITORS STYRO FLEX (BUT NOT TUBULAR CERAMIC) FOR LOWER LOSS
- IF NOT OSCILLATING, USE 'RFC' INSTEAD OF 1K2 (R_1)
- RFC_{R_1} DATA : 150 TURNS / SWG 36 ENAMELLED WIRE ON A 100K RESISTOR ½W AS SHOWN →



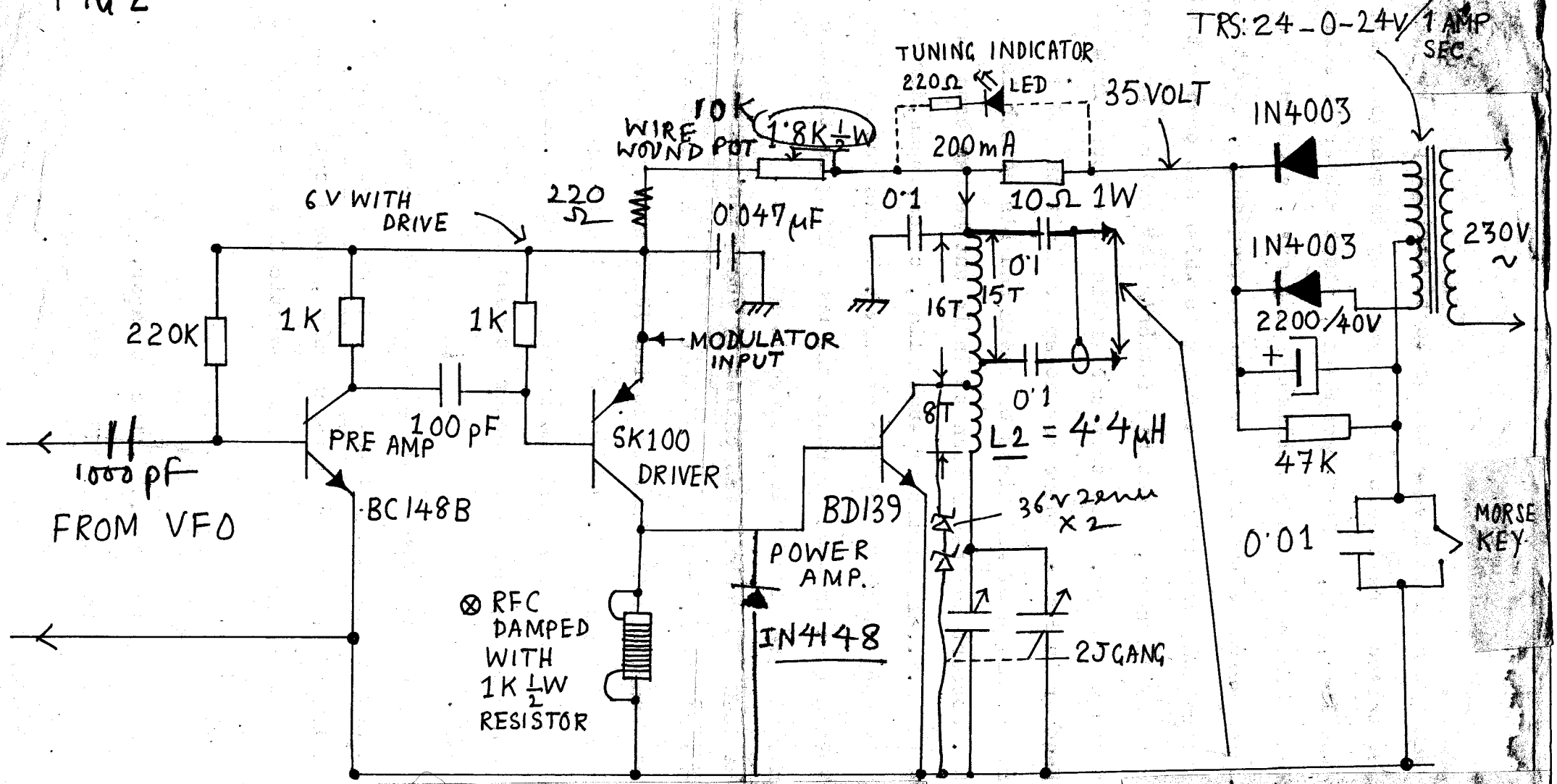
- OR INCREASE POWER FROM +6V TO +9V.
- KEEP THE OSCILLATOR AWAY FROM METAL ENCLOSURE.



1. BUFFER AMPLIFIER IS TO ISOLATE OSCILLATOR FROM THE FOLLOWING CIRCUITS (OR ANTENNA)
2. TO INCREASE POWER WITHOUT CHANGING FREQUENCY

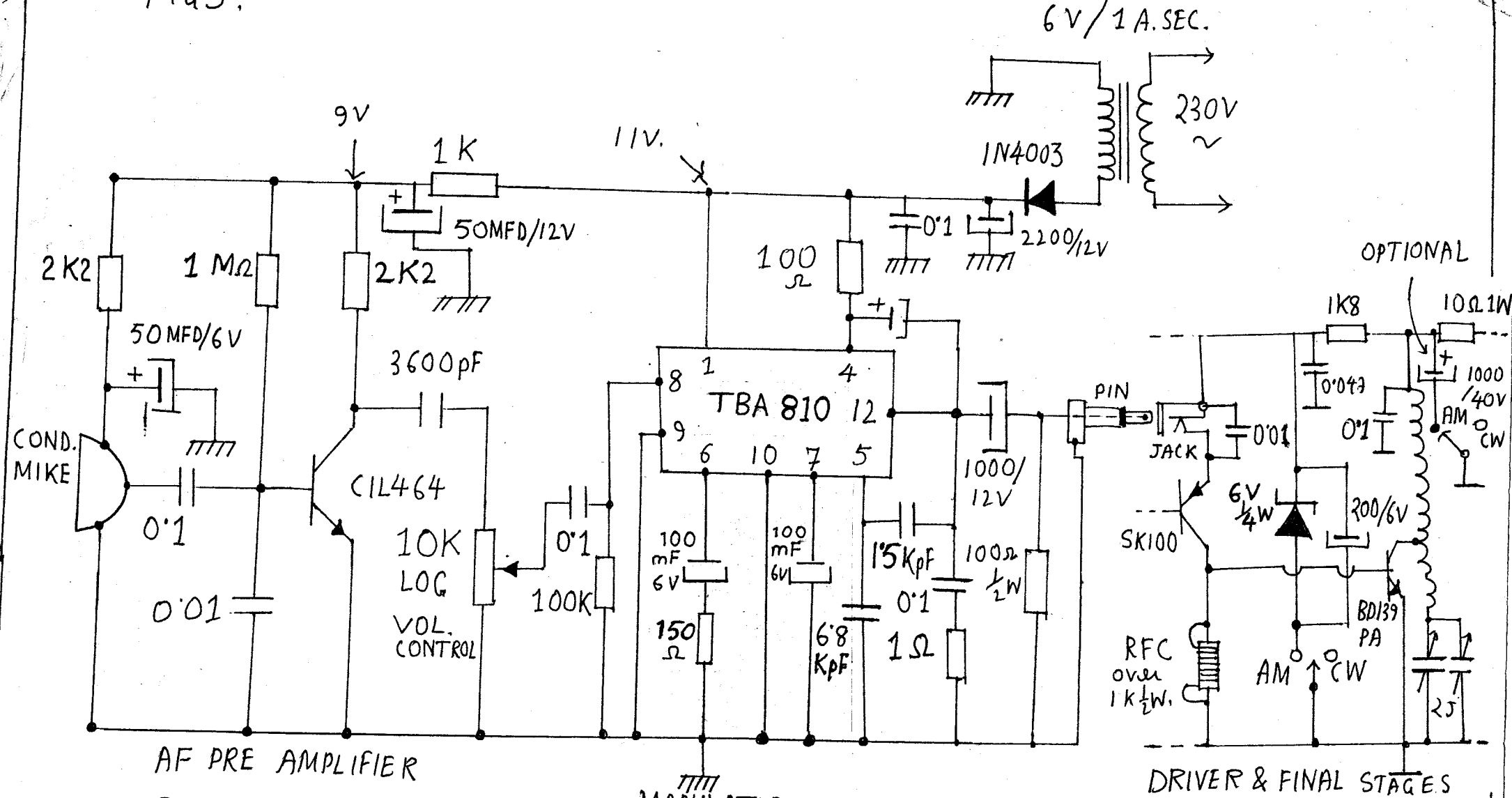
FIG 2

7 WATTS RF AMP. SECTION



collected from "QSP"

FIG3.



① NEVER CONNECT MODULATOR & TX GND TOGETHER (TO PREVENT SHORT)

② ADJ. 10K LOG FOR MINIMUM DISTORTION.

HOMEBREW AMATEUR EQUIPMENT :

7 Watt QRP AM/CW Transmitter

Collected from the Amateur
Magazine 'QSP'
Circuit by: K.R.Vasnthakumar,
VU2 VWN , Kalapurakkal,
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P.T.O.

- The pre-amplifier is an R-C Coupled one while the driver collector-load is an RFC damped with 1 K resistor in order to suppress unwanted Self-Oscillation . The base of BD 139 is directly coupled to the collector of SK 100 . The Tank Coil is placed in the collector of BD139. THE TAPPING ON THE coil ARE CRITICAL . The Antenna Connector is an ordinary Mike -connector , so two 0.1 mFd. capacitor are used for-isolating the DC. from the mike-connector .

The power amplifier pwr. supply is a full wave centre tapped one. The power transistor is with a 24-0-24 V,@ 1 Amp. secondary . Since the load current is only around 200 mAmp. , the rectified voltage will-be much higher than the rated voltage . The voltage drop across the winding will be in significant . So the output voltage from the power - supply will be around 35 Volts . A bridge rectifier circuit is not-- recommended because it causes hum in the signal .

Fig. 3 : The Modulator Section :

The modulator is a TBA 810 IC Audio Amplifier with a single transistor Pre-Amplifier. The TBA is operating on 11 VDC supply from-an eliminator and is using standard circuitry . The audio pre-amp. is a CIL 464 transistor . The 0.01 mFd. capacitor from the base of CIL464-to the ground is an RF bypass capacitor . The RF may induce in the pre--amp. while transmitting . Lower values can be used for this purpose . a 100 ohm 1/2 watt resistor is connected accross the output of the modulator . When the Tx (Transmitter) is in AM position this 100 Ohm will come in series with the emitter of the SK100 .

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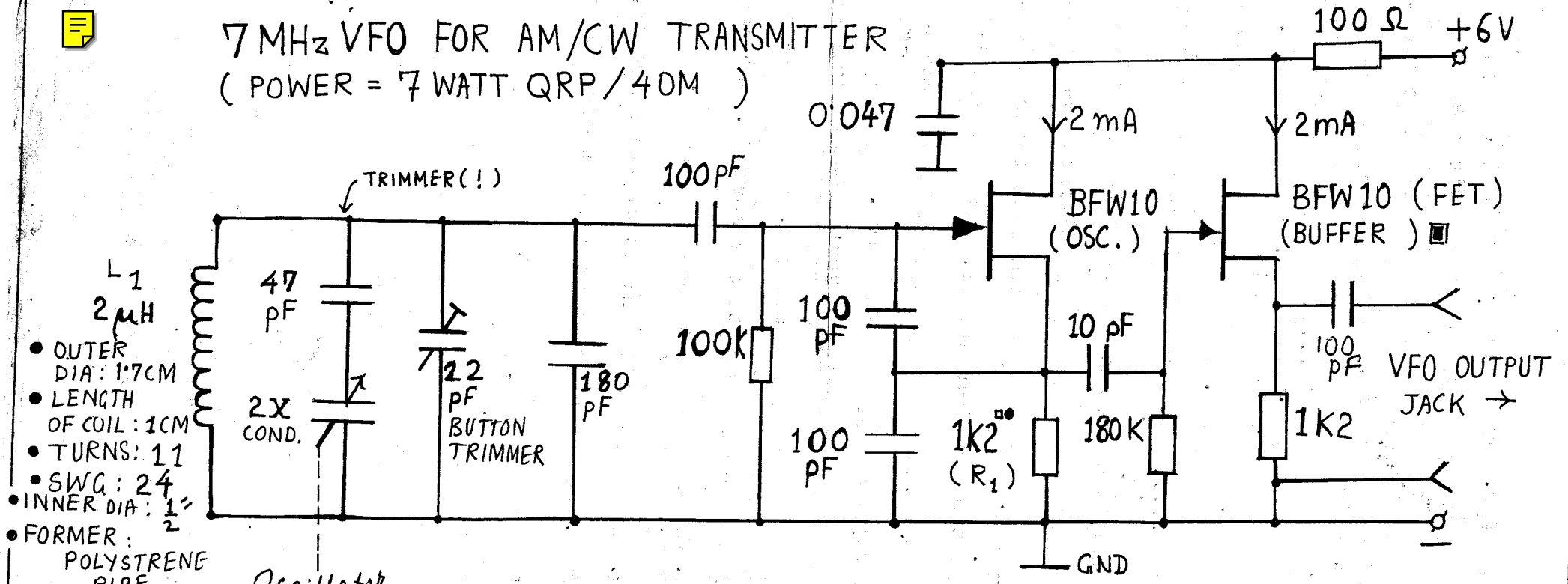
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SANDEEP BARUAH 3.7.86

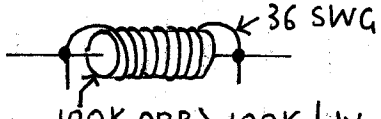
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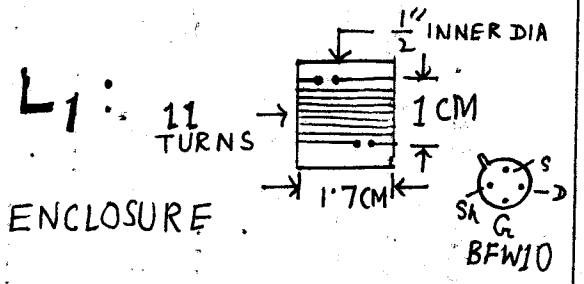
(POWER = 7 WATT QRP / 40M)



- ALL CAPACITORS STYRO FLEX (BUT NOT TUBULAR CERAMIC) FOR LOWER LOSS
- IF NOT OSCILLATING, USE 'RFC' INSTEAD OF 1K2 (R_1)
- RFC_{R_1} DATA : 150 TURNS / SWG 36 ENAMELLED WIRE ON A 100K RESISTOR ½W AS SHOWN →



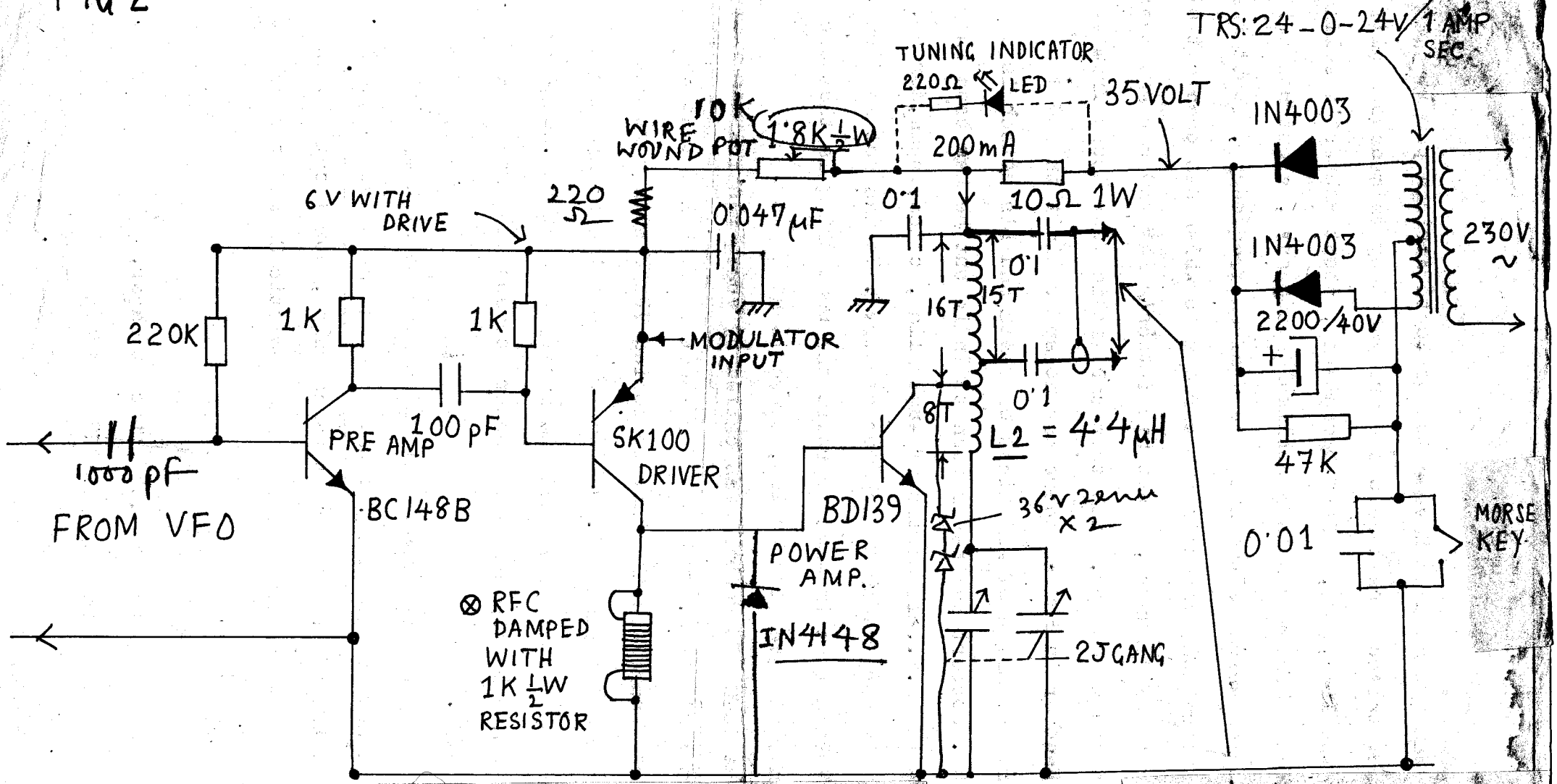
- OR INCREASE POWER FROM +6V TO +9V.
- KEEP THE OSCILLATOR AWAY FROM METAL ENCLOSURE.



1. BUFFER AMPLIFIER IS TO ISOLATE OSCILLATOR FROM THE FOLLOWING CIRCUITS (OR ANTENNA)
2. TO INCREASE POWER WITHOUT CHANGING FREQUENCY

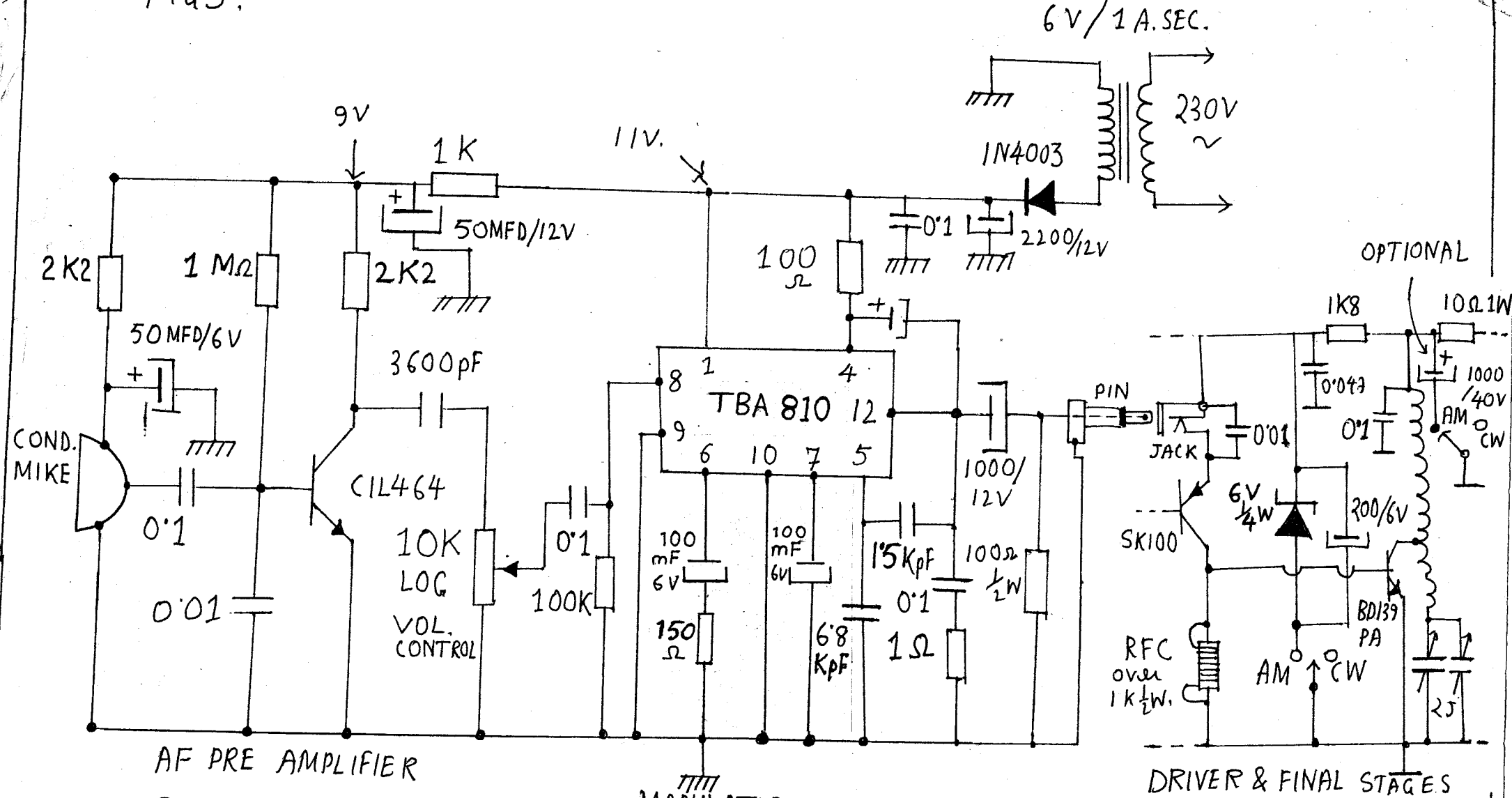
FIG 2

7 WATTS RF AMP. SECTION



collected from "QSP"

FIG3.



① NEVER CONNECT MODULATOR & TX GND TOGETHER (TO PREVENT SHORT)

② ADJ. 10K LOG FOR MINIMUM DISTORTION.



BASEMENT TECHIE

NUMBER 3

POOR BOY ⚡ LONE WOLF
ISSUE

BASEMENT TECHIE NUMBER 3

POOR BOY ⁄ LONE WOLF ISSUE

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Editor & Publisher: Tom "Ticom" Filecco
Homestead Design Works
P.O. Box 96
Plymouth, CT 06782
Email: ticom.new.england@gmail.com
Phone: (203)-FOrest4-4225 (364-HACK)

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You don't need a lot of money to become a Basement Techie. Indeed, many of us were lucky having two nickels to rub together when we started out. These days it is fortunate that there are a number of places where those of you with limited funds can put a lab together.



In Connecticut, we have the following cheap sources that are useful for the Basement Techie putting together their secret laboratory:

- Army/Navy (military surplus) stores
- Benny's
- Big Lots
- Dollar Tree (and other $1 stores)
- Dumpster diving/curbside scrounging
- Goodwill
- Harbor Freight
- Home Depot
- Ocean State Job Lot
- Savers
- Tag sales & flea markets
- Wal-Mart

Other states will have similar, if not the same, places for you to outfit yourself. If you are especially lucky, like the Basement Techies around Kingston, NY and Manchester, NH, there might be a store nearby that deals in electronic surplus. In Connecticut, Pratt and Whitney used to have a nice walk-in surplus store in East Hartford at Rentschler Field. The place was closed down a while ago, but a Cabela's is there now.

The picture on the upper right hand side of the page is my friend Wildflower's “remote” secret laboratory that is not only located in a genuine New England fieldstone basement, but is also stocked solely with stuff picked up from those very same places I just mentioned earlier.

Believe it or not, everything in that Basement Techie's secret lab was acquired via the very same sources I just described earlier. This lab is used for electronics, chemistry, and light mechanical work. We have constructed crystal sets, experimented with liquid rectifiers, and made simple test equipment like an electrical continuity tester on this bench.

In this particular instance, the workbench is a cheap folding table from Ocean State Job Lot. The bench to the right of it was made from scrap lumber. Most of us curbside scrounge or dumpster dive an old door from somewhere, and use cinder blocks or old filing cabinets as the legs. The shelf is also scrounged wood and plastic crates. Or we find an old sturdy table or desk at Goodwill, and use that as the basis for our workbench.

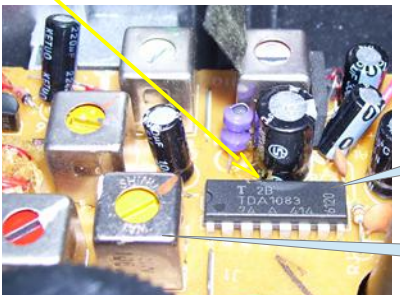
For parts storage, you see shoebox-sized plastic storage boxes from the dollar store. They are very popular amongst Basement Techies. The flat multiple compartment parts boxes are from Big Lots and Ocean State Job Lot. You find them in either the hardware or sporting goods (fishing) departments. The plastic and glass jars are re-purposed food containers (free!). I hear the glass ones are great for building your own capacitors. The re-purposed cat litter jugs are used as bins for storing larger items. The small storage tins, useful for their intended purpose or as project boxes, are a dollar from any number of places.

Tools can be had cheap from most of those places on the list. This 15 piece wrench and pliers set was $20 from the local Home Depot, and is a good beginner's value for the price. I've seen similar brand/type tools for $2-$3 each at the local job lot/odd lot stores. I have this set as part of my secondary tool kit. The quality is very good for the price, and replacements are inexpensive and available right down the road.



My favorite tool sources are tag sales and flea markets. You can find older, quality, American-made tools dirt cheap at them. I just received an email from my friend Gary, a fellow Basement Techie. At one recent tag sale he came across a World War II vintage Cattaraugus 225Q sheath knife for $5! Who knows what you will discover at your local tag sales? Only one way to find out!

Both the police scanner and the AM/FM radio were found for a few bucks each at local Goodwill stores. While it would be a sin to gut an old working Zenith or other All-American Five radio for parts, I have no issues with deconstructing late model solid-state boomboxes down to their essential elements. Keep your eyes open for that TDA1083 IC. They are useful to have around.

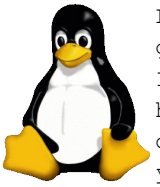


Police scanners make great VHF/UHF test receivers, and are still useful in many places for keeping an ear on the locals. At the very least you can use them to monitor the 160 MHz. NOAA Weather Radio channels. The last police scanner I bought at Goodwill (for $5!) had the NOAA weather alert feature so you can keep it on standby and get notified when heavy weather is heading your way. This is handy when you're working in a basement and can't see the sky.

If you are lucky, you may have within listening range a cool FM pirate or college radio station that does not play regurgitated shit. The AM broadcast band comes into its own late at night, when many Basement Techies cruise the electromagnetic aether seeking A Certain Truth. In Cybertek #9, there is an article called *"Doing a Radio!"* that shows you how to convert a Walkman-style radio for shortwave reception.

Computers are everywhere. Just check out local tag sales, flea markets, and thrift stores for late model working machines and parts. Those of you in Southern New England are especially lucky as you are withing driving distance of the famous MIT Flea, a combination hamfest/electronics flea market held every third Sunday from April to October. You can find all sorts of interesting stuff there, and cheap used computer equipment.

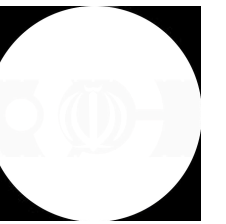
Open source software is the choice of the Basement Techie. Forget about Microsoft Windows. Install Linux or BSD on your machine and you are good to go. You can download these OSes for free off the Internet, or find a local user group or hackerspace. Someone there will have their distro of choice, and be more than happy to help you. Open Source operating systems are a religion of their own. Every OS has its devotees and detractors, and much time is spent debating the merits of one OS over the other. For what it's worth (admittedly, not much), I've found Ubuntu to be very easy to get running, and non-computer people seem to take well to it. I also like Knoppix, and for older hardware, Puppy Linux and Damn Small Linux. If you are just starting out, your best course of action at first is to run what the local Linux gurus prefer. Once you get some experience under your belt then you can branch out into something else if you'd like. Then eventually you'll become the Guru, and be able to help others.



Possibilities are almost unlimited with the cheap (sometimes free) availability of cast-away hardware and open source software. Just about any “obsolete” computer you care to get up and running is still a hell of a lot more powerful than the computers that sent us to the Moon.





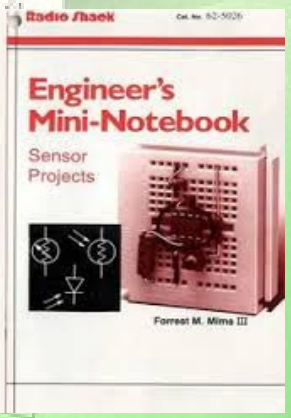


Electronics

was my first foray into the realm of technological experimentation. Many Basement Techies start out this way because it's cheap, easy, and doesn't take up much space until you get that first 19 inch rack full of test equipment.

There is a lot of information about electronics on the Internet. So much info that people have a hard time with it all. I've mentioned the Navy Electricity and Electronics Training Series (NEETS) many times before. It's a free download, and very good. However it doesn't show you how to go and do stuff. There are a lot of websites that have electronics projects, but you are left wondering what's going on. A lot of Arduino stuff is like that, but then again the Arduino, as good as it is, was designed for hipster artist types with little electronics background to incorporate tech into their art projects. It's all good if that's your gig, but for those of you who really want to get your hands dirty there's always the left-handed path.

When we started learning about electronics back in the day, we went down to our friendly local Radio Shack and picked up Forrest M. Mims III's book Getting Started In Electronics. It was only 128 pages long, but it not only taught you electronics, but also showed you schematics of various circuits you could build, most of which were interesting and useful. We also bought all the volumes of his Engineer's Mini-Notebook series. Plenty in those books to get in trouble with! Radio Shack still sells these books, and they are the best for learning about electronics and building useful gadgets.



Since I bought the Mini-Notebooks many years ago, Mims has consolidated the many volumes into a fewer number of larger books. The two best volumes in the current set are Electronic Sensor Circuits & Projects, and Science and Communication Circuits and Projects. If you are of a certain bent, you will find these two the most useful of the collection.

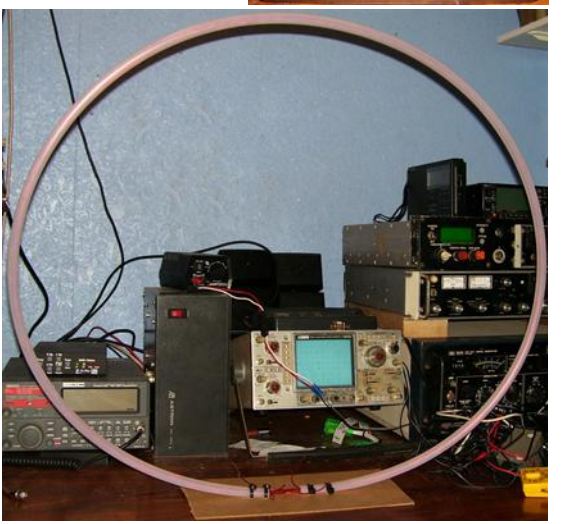


AM BCB Reception Experiments

The AM Broadcast Band (AM BCB) is an interesting place to experiment in. Equipment is cheap, and you can build a lot of stuff out of junk parts. I've played around with mineral detectors made from plumbing parts and a piece of Galena, and tuning coils wound by hand on an oatmeal box. This primitive homebrew gear actually performs comparably to the consumer electronics stuff.



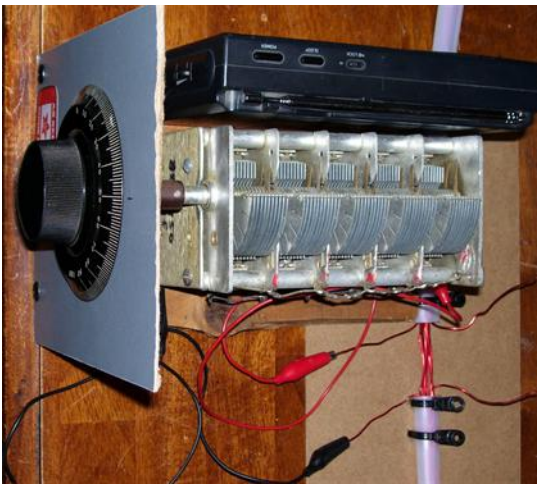
My usual receiver for AM BCB reception and testing is a 20 year old Radio Shack DX-375 Portable. There's nothing special about it other than the fact that it was on clearance at the time, but it turns out that it is a fairly well-respected portable among the AM monitoring community.



After reading W7OIL Dan Peterson's article in the 2008-2009 Xtal Set Society Newsletter Collection, I went to the local Dollar store and bought a hula-hoop. It's a plastic tube about

1/2" thick and 30" diameter. Found a length of 16 ga. enamel wire and discovered that 9 turns would fit in the tube. That's roughly 70 feet of wire. The wire broke after the 6th or 7th turn, so there's actually two loops of wire in there.

I took my "experimenters tuner", an 80-1750pf air variable capacitor, and attached it in parallel to the loop. These large variable capacitors are getting hard to find, but if you check out your local hamfests you should come across one. The Velvet Vernier dial was also a hamfest find. While not absolutely necessary, it does make tuning a lot easier. The internal loopstick antenna on the DX-375 coupled nicely into the larger loop antenna assembly by placing the radio as shown.



In tuning around, I was able to receive a number of stations on the low end of the of the band. Reception on the antenna seemed to stop around 900-1000 KHz. By taking the smaller loop and wiring it in opposition to the larger loop, I was able to increase the top end to 1100-1200 KHz.

With this arrangement, you will know the antenna is tuned properly as you will get a definite “peak” in the audio of the received station when the capacitor is tuned to the right spot. This antenna is also bi-directional with the pattern broadside to the loop, and nicely nulls out signals off to the sides of its pattern.

Keep your eyes open. There's a lot going on that you should stay abreast of in the hobbyist scene. Here are a few things I'm working with and watching.

Radio receiver technology keeps getting less expensive. It started with the **FunCube Dongle** USB SDR, and its 64-1700 MHz. frequency coverage for under $200. They now have a version with 150 KHz. to 1.9 GHz. Coverage for the same price. Then a guy named Eric Fry discovered that European DTV USB receivers with the RTL2832U demodulator can be turned into a wideband SDR. This will continue to open up new worlds of digital signal reception for communications monitoring hobbyists. SDRs are also being seen in the transmit side with inexpensive radios like the Flexradio **Flex-1500**. The nice thing about all this is that in addition to communications monitoring, all sorts of radio science observing becomes a lot easier.

A guy named Massimo Banzi developed an electronics prototyping system, actually a microcontroller system, called The **Arduino**. It's cheap, and people keep finding new amazing things to do with it every day. It was designed for non-techies and is very easy to implement projects with.

Finally we have the **Raspberry Pi**, a credit-card sized Linux computer for $25. It's reminiscent of introductory computers like the Commodore VIC-20 and Timex/Sinclair 1000, only a lot more powerful. Much like the Arduino, people keep finding new and amazing things to do with it.

Imagination is the limit with all this stuff, and even someone on a budget can get involved. There is also a well developed community around it all to help you out, even if you are a lone wolf Basement Techie like most of us.

Freedom to create is in your hands. So jump in and get started. Pick up an RTDL SDR or a Funcube Dongle and a Raspberry Pi. Some folks have already done some work putting the two together Do a little prototyping with an Arduino, and learn to program interactivity. The sky is the limit!


WLAT - AM910
Farmington, CT



Prepared by MagCloud for Mike Dank. Get more at hdworks.magcloud.com.

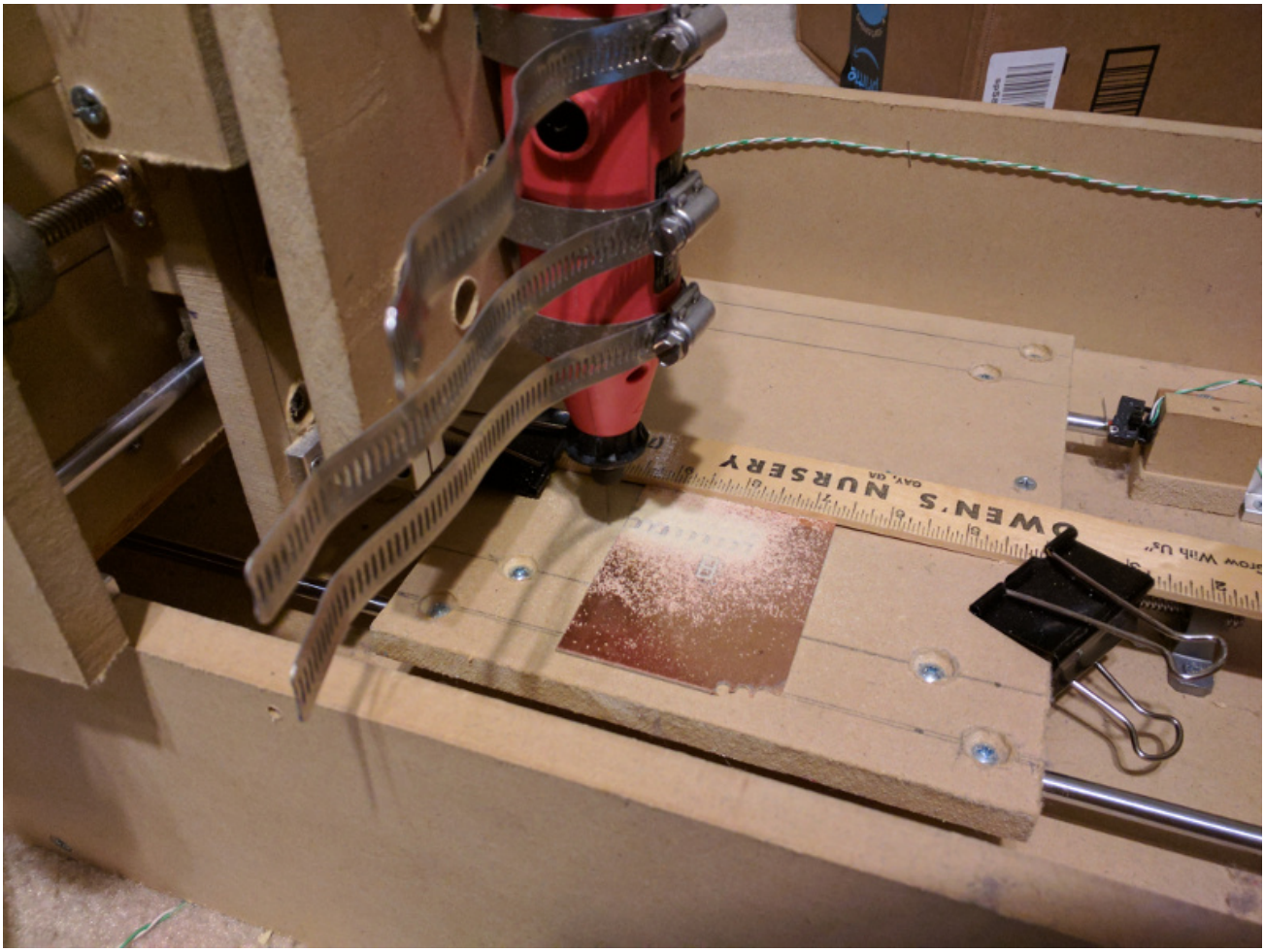
circuit construction techniques

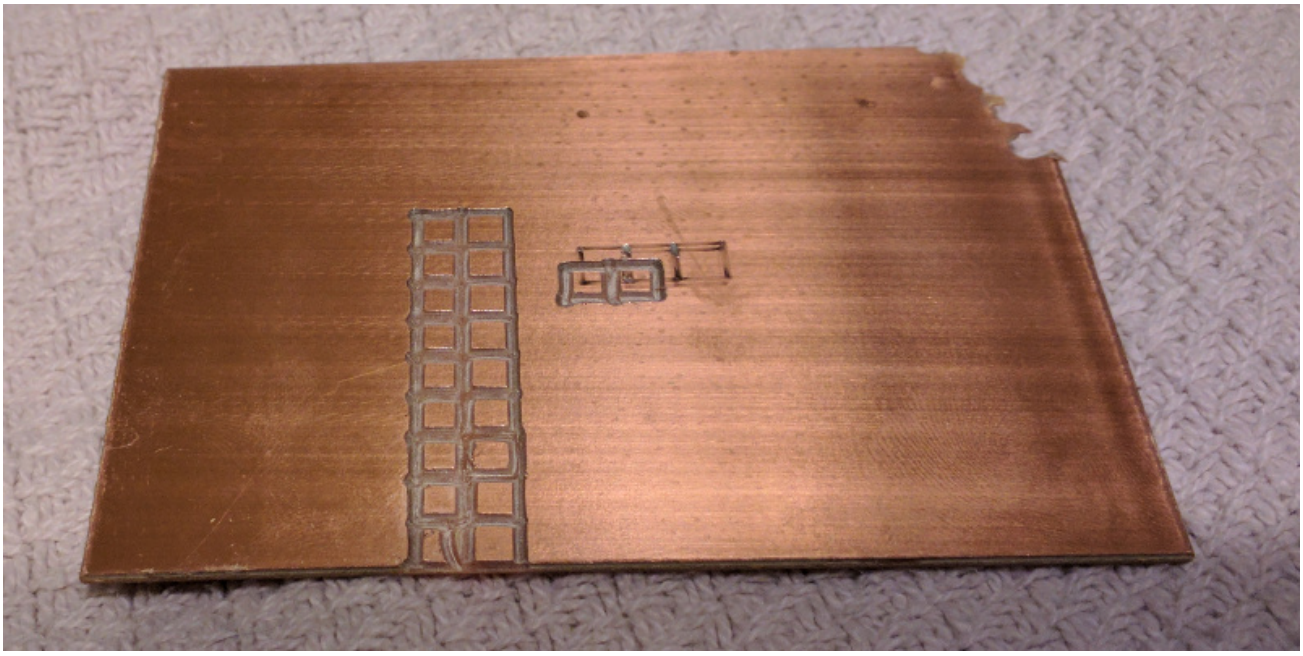
PUBLISHED JANUARY 10, 2018

A while back, I built a desktop cnc machine with the intent of milling circuit boards. Well, I finally got around to playing with it.

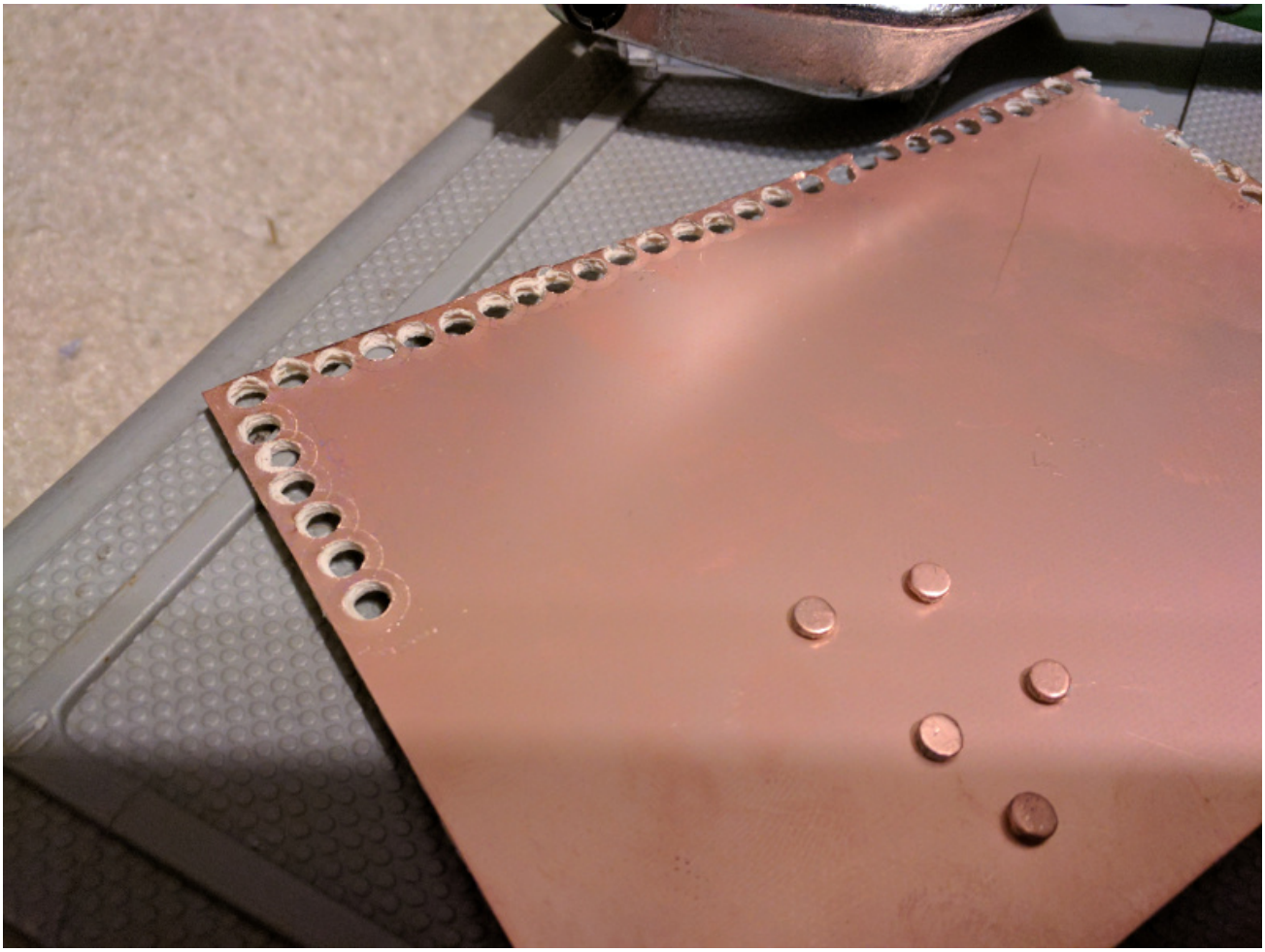
The spindle is just a cheap rotary tool with one of the drill bits that came with it. I really need to get and end mill bit. The drill bit skips around a bit, but it does work.

Below is a photo of the first run and the end result. You can see a few test runs that didn't work out too well, but once I familiarize myself with the cnc software and the machine itself, hopefully I'll be able to make some decent boards.





Next, I wanted to try some manhattan construction using k7qo's method of punching out copper islands.I picked up a cheap sheet metal punch off amazon as well as some cem copper clad boards and tried it out. The method seems to work okay. I've punched out quite a few islands and now I just need to use them and see if it works better than cutting them with my drill press.





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The NT7S POTLUCK & QRP-L.ORG GROUP PROJECT RIG
Designed by Jason Milldrum, NT7S

Brief Circuit Analysis and Test Procedures
by Paul Harden, NA5N

CONTENTS:

1. Introduction & Rig Description
2. Local Oscillator
3. Receiver Circuitry
4. Audio Stages
5. Transmitter Stages
6. Appendix (Volt-dBm conversion & photos)

1. INTRODUCTION & RIG DESCRIPTION

INTRODUCTION

Jason Milldrum, NT7S, was the winning entry of the 2007 Potluck design contest. For those expressing interest in building the rig "Manhattan style," Jason developed the circuit further into the "QRP-L.org Group Project."

The protype was sent to Paul Harden NA5N for testing. This document briefly describes the theory of operation and testing procedures for those building the rig. Though an oscilloscope is not necessary to get the rig working, many QRPers now have scopes, for which this document is intended. The waveforms demonstrate how the rig works, and how to use your scope to analyze or troubleshoot radio circuits. For those without a scope, the displays will help you "see" how the circuit works.

RIG DESCRIPTION

The NT7S Potluck/Group Project rig is a direct conversion transceiver for 20M. In spite of the minimal parts count, the direct conversion receiver has good sensitivity and gain; the transmitter provides a solid 5W.

VFO/LO. Jason mixes a 4MHz and an 18MHz oscillator to generate the 14.009-14.087MHz tuning range of the rig. By changing one of the crystal frequencies, it can be easily adapted to other ham bands. RIT is also included.

Good VFO filtering and amplification provides a nice, clean 14MHz LO sinewave to the rig. A power splitter forms the required 50Ω receive (RXLO) and transmit (TXLO) signals, each being about +15dBm, or considerably more LO power than most QRP rigs.

Receiver. The NT7S rig is a direct conversion (DC) receiver. Ample 14MHz band pass filtering attenuates out-of-band signals, a common ill of many DC receivers. A 12dB RF amplifier improves the sensitivity of the receiver.

Product Detector. Jason uses a double balanced mixer, using two trifilar wound toroids and 1N4148 diodes, to achieve a robust mixer. The 14MHz RF and 14MHz LO is mixed - directly forming the audio, and hence the name, "direct conversion."

The audio output of the product detector is well terminated and followed by an active CW filter and several stages of audio amplification.

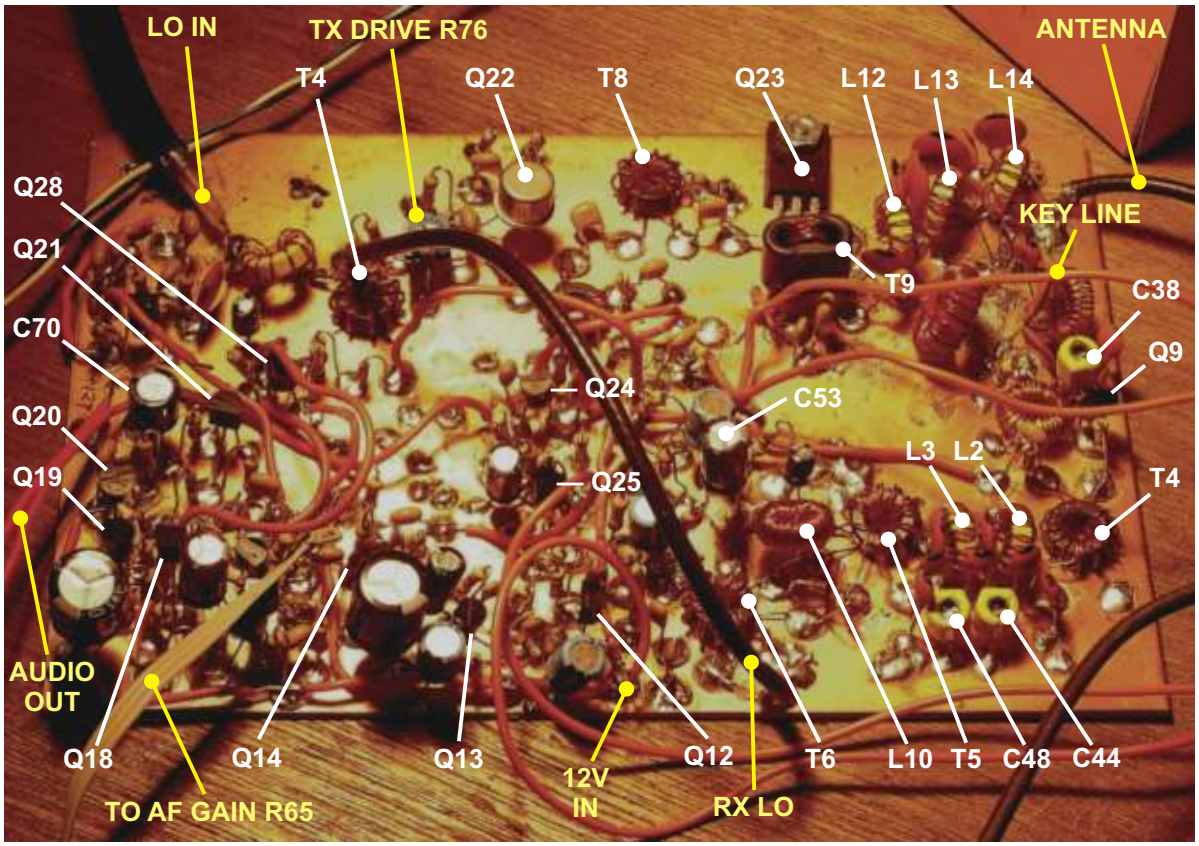
Audio output amplifier (Q19-Q21) is a totem-pole driver (NPN-PNP pair) for high current drive, suitable for low impedance earphones and not starved for gain.

Transmitter. The +15dBm TXLO simplifies the transmitter gain stages. A single TX driver (2N5109 Q22) is all that is needed to drive the PA. The TXLO signal is applied to the TX DRIVE pot, allowing output power to be adjusted over a few hundred mW to a bit more than 5W.

A 2SC5739 (Q23) is used for the PA to easily make the full-gallon 5W output.

The 7-pole low pass filter easily knocks down the 2nd harmonic to 54dB below the carrier, with the 3rd harmonic barely discernable on a spectrum analyzer, greatly exceeding FCC compliance for harmonic rejection.

Major parts locations on the prototype
(Differs slightly from the QRP-L.org group project layout)

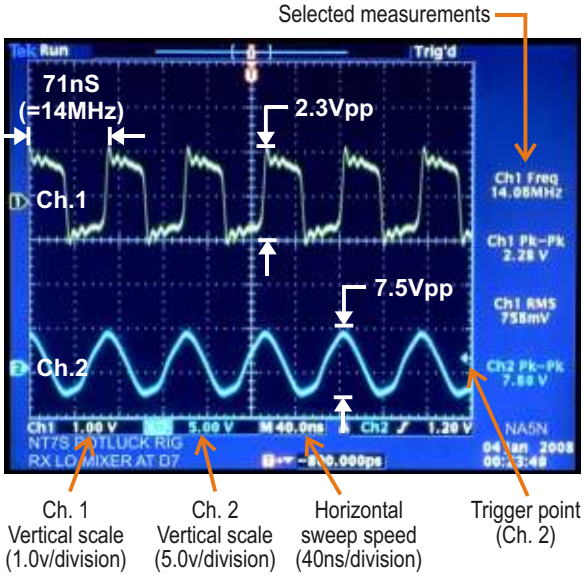


RIG TESTING

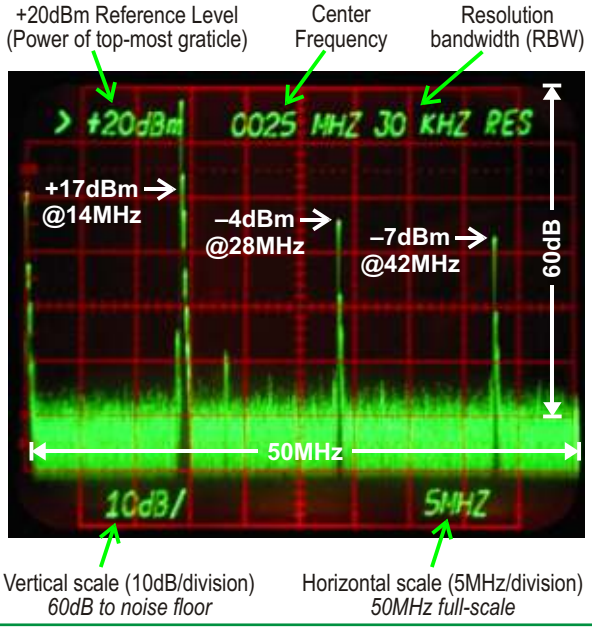
I used my trusty Tektronix 475 scope and 7L13 spectrum analyzer (circa. 1970s) in my home lab. I also used a Tek TDS3032 for the scope photos (better display for photos).

The oscilloscope and spectrum analyzer displays used in this document are described in the photos below for those not familiar with the displays. They are very similar to most any make of these test instruments.

Oscilloscope Display



Spectrum Analyzer Display



2. LOCAL OSCILLATOR

HETRODYNE VFO

Jason chose to generate a tunable 14MHz VFO by mixing an 18MHz crystal oscillator with a 4MHz oscillator using a ceramic resonator. The 4MHz resonator is varicap (MV209) tuned for the tuning range. With this scheme, Jason covers the majority of the 20M CW band, from 14.009 to 14.087 MHz.

The frequency of a ceramic resonator can usually be pulled greater than that of a crystal. The 78 KHz range is .078MHz/4MHz=2%, or greater than the 0.5-1% pulling range of a crystal.

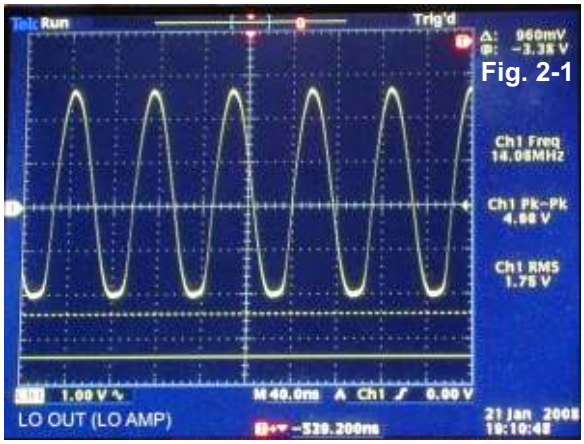


Fig. 2-1

CH.1: 14 MHz LO out at C29 (5Vpp, +18dBm, 50Ω)
CH.2: Not used

Another MV209 varicap bends the 18MHz crystal for the RIT, yielding a 1700 Hz RIT range, or about ±800Hz. (RIT removed during transmit).

The 14MHz from the 4 and 18MHz mixer is filtered and amplified to about +18dBm by two 50Ω amplifiers, as shown in **Fig 2–1** and **Fig 2–2**. This LO is split and used by both the receiver and transmitter sections (RXLO and TXLO).

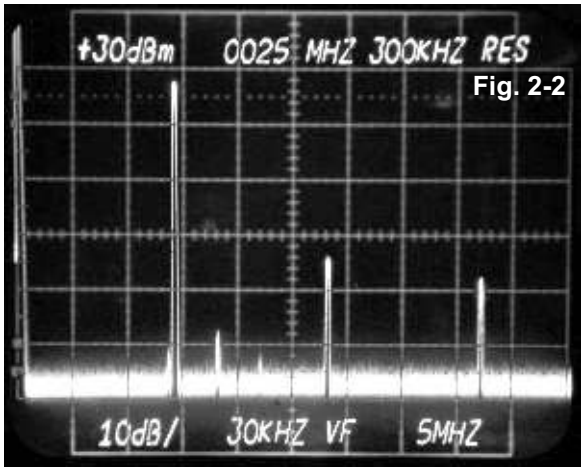


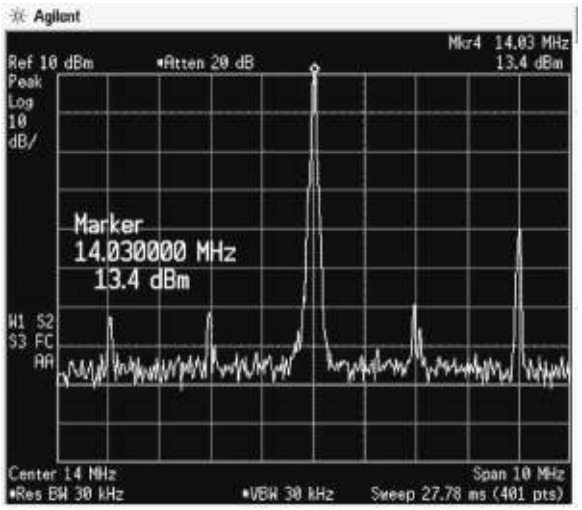
Fig. 2-2

Spectrum display of the 14MHz LO, +18dBm

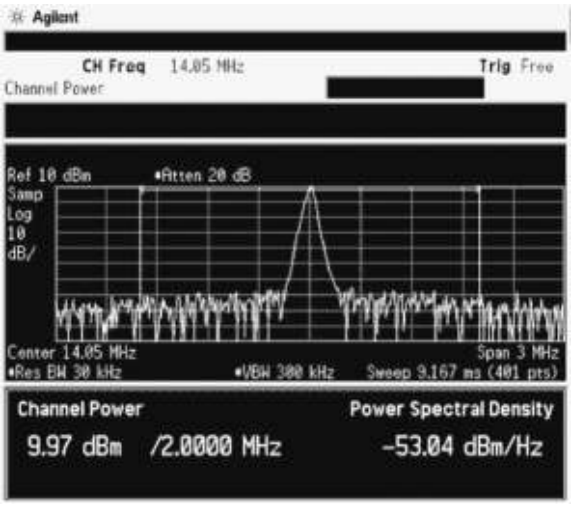
Below are some displays from an Agilent E4406B spectrum analyzer ($35K+) just to demonstrate the displays of modern instruments. While the basic spectrum display remains unchanged from the older spectrum analyzers, the big difference are the built-in measurement options. In these displays, the harmonics and phase noise of the



Agilent E4406B listing of harmonic power for the RXLO



Spectrum of the RXLO on Agilent E4406 SA



Agilent E4406B LO phase noise display

3. RECEIVER CIRCUITRY

RECEIVER "FRONT END"

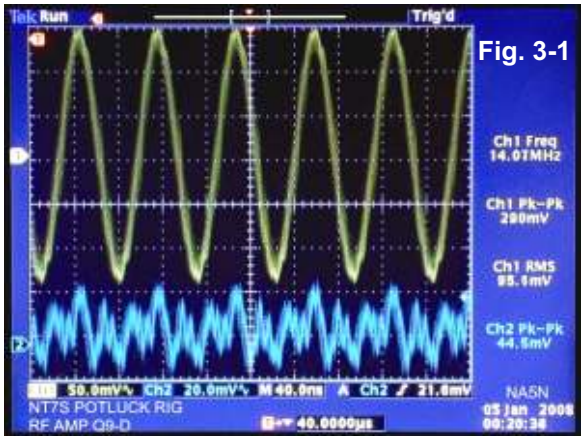
Testing the receiver involves injecting a known signal into the antenna port. I inject -30dBm from a signal generator. This is a strong signal, equating to 20mVpp. This is the minimum sensitivity of most o-scopes and makes a nice level to trace through the receiver without causing gain compression.

(Note: There is a table for converting volts p-p to power in dBm on page 11)

The signal levels of the RF amplifier (RFA) are shown in **Fig 3-1** with 44mVpp input (Q9 source) and 290mVpp output (Q9 drain) for a ***voltage gain*** of:

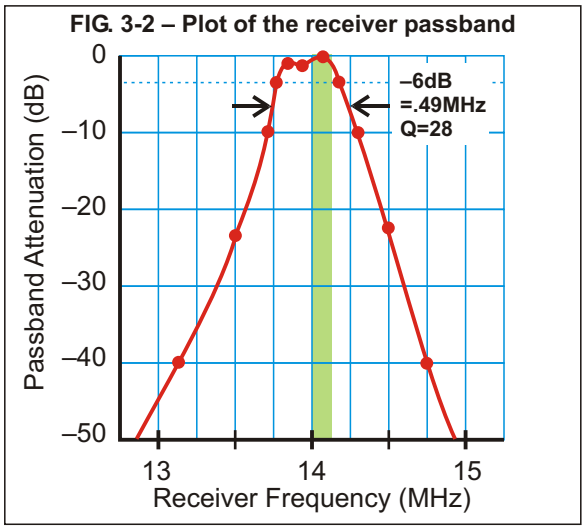
20log(290/44mVpp) = 20(6.6) = 16dB

Of the 20mVpp signal input, about half is getting to the RFA due to losses through the low pass filter, T-R switch and preselector. The RFA easily makes up for these input circuit losses.



CH.1: RF amplifier output (290mVpp, -7dBm)
CH.2: RFA input (44mVpp, -25dBm)

FIG. 3-2 – Plot of the receiver passband

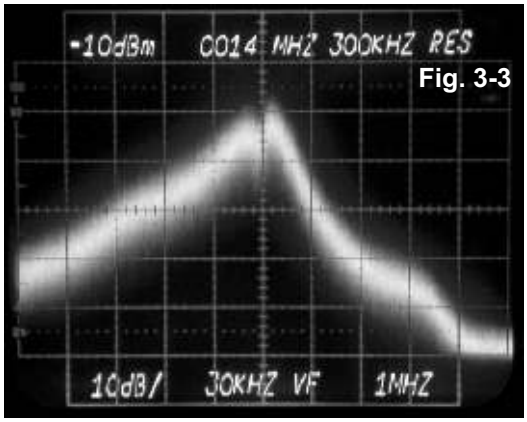


The spectrum analyzer shows the ***power gain*** of the RFA closer to 13dB with a 50Ω load. By measuring the input and output signals on a scope, you can verify the operation of the RFA (or any amplifier) and calculate the gain in dB.

Following the RFA, the signal is further band-limited by a 2-section 14MHz band-pass filter (BPF) consisting of L8, L9 and associated capacitors. The output of the BPF at C48 is shown in **Fig 3-2**. The plot was made by manually recording the peak-peak voltage on the scope at different frequencies (Vf) compared to the peak voltage (Vp) - occuring at 14.05MHz in this case - then converted to dB by:

dB=20log(Vp/Vf)

The -6dB half-power bandwidth of **Fig 3-2** is about 480 KHz, or Q=14MHz/.48MHz = 28. Since this is measured *in the circuit*, this is the loaded Q of the filtering. You should get similar results.



Spectrum display of the RF amplifier Q9 output by injecting a noise source at the antenna jack – before the 14MHz bandpass filter.

Noise Sweep. Another interesting means to plot the response of a circuit, particularly filters, is to inject a noise source and look at the output on a spectrum analyzer. This noise technique sweeps all frequencies instantaneously and will "paint" an exact picture of the response on a spectrum analyzer.

Injecting about -40dBm of noise into the antenna port, the response at the output of RF amp Q9 is shown in **Fig. 3-3**. This shows the combined effects of the receive path through the output low pass filter and the L6-C38 pre-filter. The slight hump at 17MHz is the cutoff of the PA output low pass filter.

Fig. 3-4 shows the noise sweep at the output of the 14MHz bandpass filter, measured at the junction of C48-C49, or the 50Ω RF input to the product detector. The narrower the input response is to the product detector, the better, for rejecting out of band signals. This is especially true for a DC receiver with no IF filters.

Part of mainting the narrow bandwidth, or the high loaded Q of the 14MHz bandwidth filter, is with proper impedance matching throughout. On the input side, the output impedance of RFA T5 is matched to the filter by the split capacitor network C41-C42. The output of the filter is matched to the input of the product detector in an identical manner.

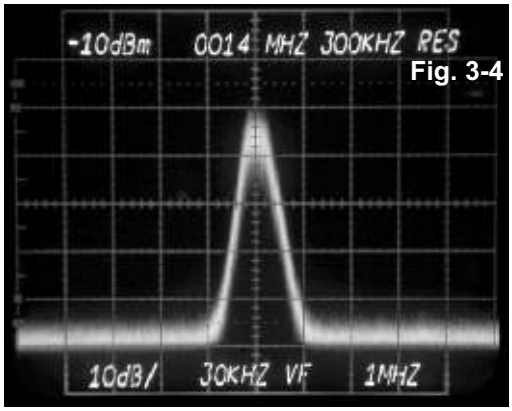


Fig. 3-4

Spectrum display of the receiver passband, similar to Fig. 3-2, by injecting noise into the receiver and measured at the product detector RF input.

PRODUCT DETECTOR - RF/LO INPUTS

The product detector mixes the 14MHz RF with the 14MHz LO to form the audio. The LO is offset from the RF slightly to form the CW audio tone.

LO Port. The +13dBm LO applied to the product detector at T7 is shown in **Fig 3-5**. The square wave appearance is due to the mixer diodes quickly turning on and off. The high LO drive raises the P1dB (1dB compression point) of the mixer for better strong signal performance.

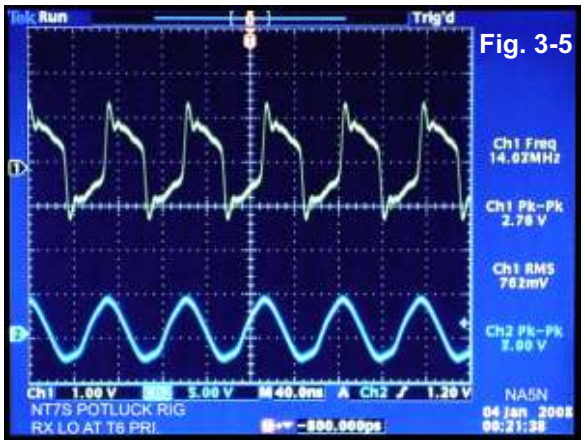


Fig. 3-5

CH.1: RXLO input to mixer (2.8Vpp, +13dBm)
CH.2: LO input from VFO (8Vpp, +21dBm)

The measured P1dB is about -14dBm, implying an IP3 around 0dBm. This was measured by plotting the RF input vs. audio power at Q10 and Q14 for the compression point. P1dB could not be measured directly at the product detector due to the presence of the 14MHz LO.

RF Port. RF applied to the product detector is shown in **Fig. 3-6**. The ratty looking signal is caused by the LO, harmonics and other images superimposed on the RF port. If this were not a double balanced mixer (DBM), it would be worse! The LO ripples appear to be about 40mVpp, compared to the 5Vpp (+13dBm) LO is about 42dB isolation between the LO-RF ports. (20log(5V/40mVpp). 30-35dB isolation is considered good for a "roll your own" DBM.

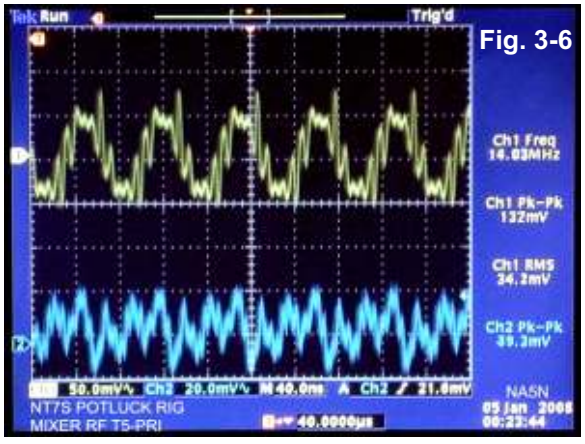


Fig. 3-6

CH.1: RF T5 mixer input (132mVpp, –14dBm)
CH.2: RFA input (39mVpp, -25dBm)

MDS. The minimum discernable signal (MDS) measured was -128dBm. Jason measured -131dBm on his. This is the point where the signal is no longer heard (discernable) and requires a signal generator with very little leakage to measure. In addition to slight differences in layout, I figure the 3-4dB difference in MDS is due to my 50+ year old ears vs. Jason's much younger ones. Regardless, this rig competes well with most QRP rigs that generally sport around -120dBm, such as an NE602 based transceiver. I was surprised the MDS measured was this good.

Dynamic Range. With -128dBm MDS, and a P1dB of -14dBm, the dynamic range is the difference, or 114dB. This is quite respectable for a DC receiver.

4. AUDIO STAGES

PRODUCT DETECTOR - AUDIO (IF) OUTPUT
In a direct conversion receiver, the audio stages are very important. This is where most of the receiver gain is developed. Jason's design is well thought out for plenty of clean audio.

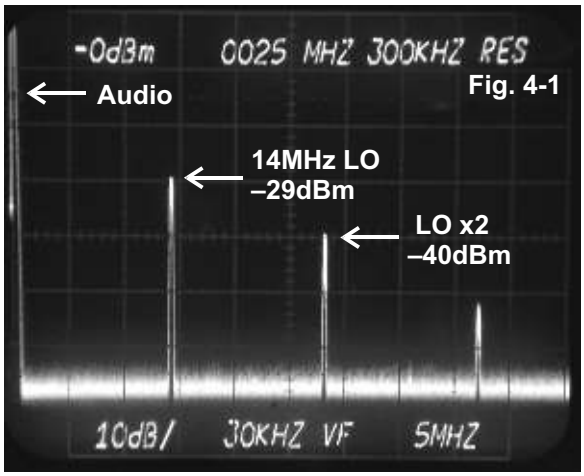
IF Port. The mixer IF output is 50Ω terminated by the diplexer components to match the product detector impedance. **Fig 4–1** shows the IF output (before the diplexer at C50) consisting of audio, 14MHz LO and LO harmonics. Audio is the desired product.

Port–Port Isolation. LO power is +13dBm; LO on the IF (audio) port is -29dBm, a difference of 42dB, meaning 1/10,000 of the LO signal is leaking through to the IF port. 42dB LO-IF port isolation is very good for a homebrew mixer.

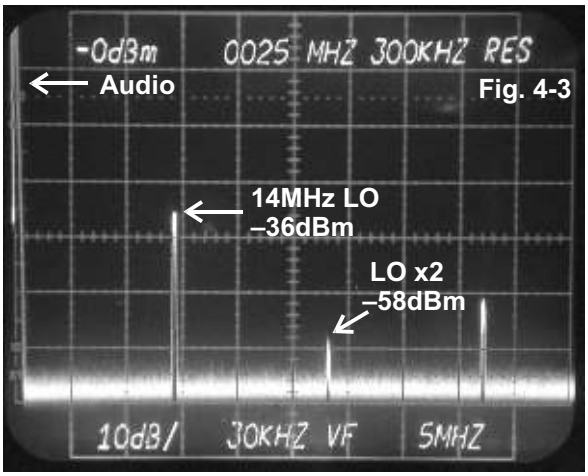
An o-scope will show the relatively weak audio signal at the product detector output when the VFO is tuned to the signal generator (or on-air signal) to produce the desired sidetone, as shown in **Fig 4–2**. The ill defined audio signal at the product detector output (bottom trace) begins to take form after the 12dB gain of common base audio amplifier Q10-Q11 (top trace). An on-air signal will appear much smaller.

The output spectrum of the 1st audio amplifier at Q10 collector is shown in **Fig 4–3**. The unwanted LO signals are knocked down another 10dB, although most of what is measured is the +13dBm LO floating around the circuit.

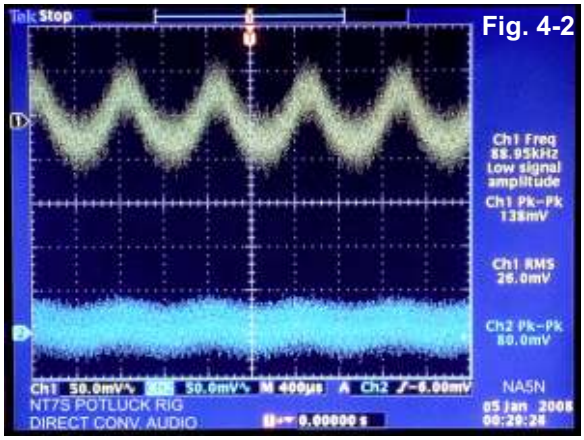
A spectrum analyzer is not particularly useful at this point in the circuit, except to demonstrate the unwanted frequency components found on the IF output of *any* mixer stage. Also, the audio power level shown (+10dBm) is meaningless over the frequency range (5MHz/div) and bandwidth resolution (300kHz) in use.



Spectrum of Product detector 50Ω output



Spectrum of 1st Audio Amplifier Q10 output



CH.1: Output of 1st Audio Q10 (140mVpp)
CH.2: Prod. Detector output (about 30mVpp)

CW Filter. Following the 1st audio amplifier, stages Q12 and Q13 form an active audio filter. If you monitor the output of the filter at Q13 (or Q14) at different sidetone frequencies, you will see the level remains relatively flat to about 3KHz, then begins to roll off at higher audio frequencies.

This verifies that the CW filter low-pass action is working properly. Also, since this is a direct conversion receiver, a plot of the frequency response will be identical on both sides of zero beat (LSB and USB sides).

AUDIO OUTPUT

The low-level 40mVpp audio from the CW filter (with -40dBm injected at the antenna) is amplified to 2Vpp by high-gain preamp Q14 for about 33dB gain.

Overload. Audio becomes distorted in any receiver on very strong signals (or poor design), caused by the amplifiers in gain compression. **Fig 4–4** illustrates *gain compression*. With –10dBm input to force an extreme overload condition, the output of Q14 goes from cut-off to saturation, forming a raspy sounding square wave. From –128dBm MDS to –14dBm P1dB, a clean sinewave audio should be seen at Q14 collector.

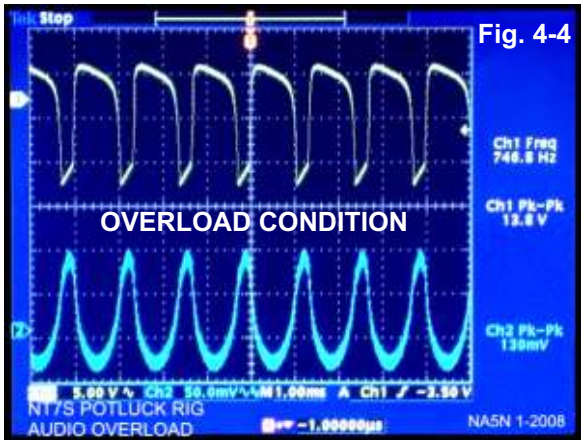
The following audio waveforms and measurements are based on setting *AUDIO GAIN R63 for 500mVpp on the wiper (700-800Hz tone).* This places 500mVpp on amplifier Q18 base, producing 2.4Vpp collector output for an additional gain of 14dB. This is shown in **Fig. 4–5**.

Output amplifier. The output of amplifier Q18 is direct coupled to Q19, an emitter follower, which drives complimentary output pair Q20 (NPN) and Q21 (PNP).

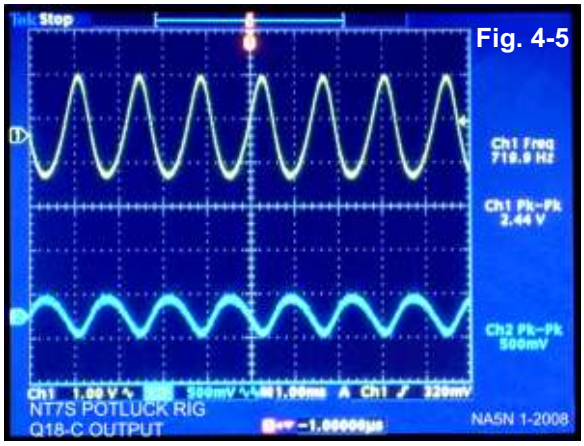
Crossover Distortion. Diodes D11-D12 offsets the base bias to prevent *crossover distortion*. **Fig 4–6** shows the result by bypassing the diodes (Sorry, Jason). As seen, it is a dramatic effect distorting the output gain. With D11-12 there is no crossover distortion on the audio output.

Output transistors Q20-Q21 can be thought of as NPN-PNP emitter followers. They provide *current gain*, but no voltage gain. The output audio, shown in **Fig 4–7**, is 2.32Vpp, or about the same as the output of *voltage amplifier* Q18.

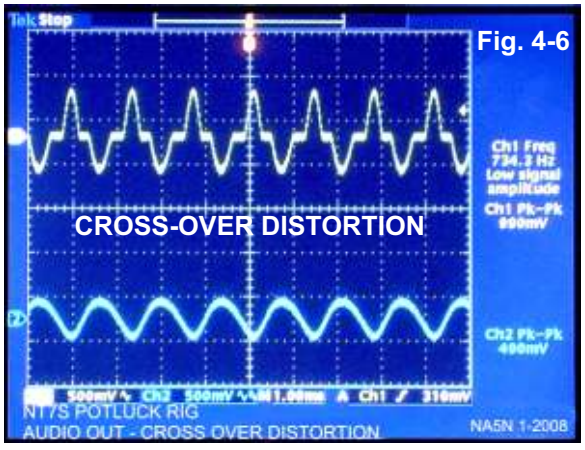
At this point, it is current that is needed to drive low impedance earphones or a speaker. About 500mVpp into earphones is generally sufficient for comfortable listening, showing Jason's audio chain (2.3V output) has plenty of gain for weak signal work. I had good results with 8Ω, 24Ω, and 32Ω head phones, with the best "sound" (to me) with the 24Ω earphones. Note the clean audio sinewave output in **Fig 4-7** from the rig.



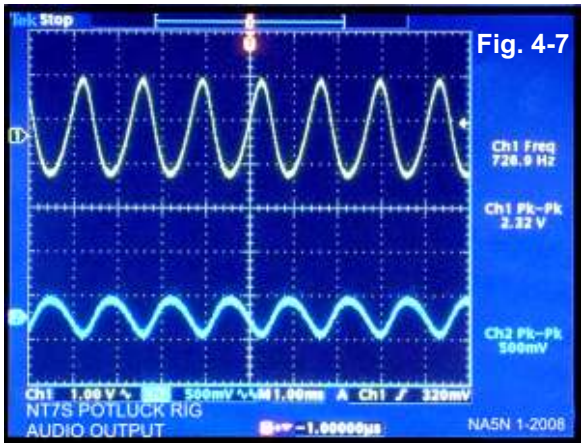
CH.1: Audio Amp Q14 out (13Vpp)
CH.2: CW Filter output (140mVpp)



CH.1: Output driver Q18 (2.4Vpp)
CH.2: AUDIO GAIN R65 set to 500mVpp



CH.1: Output driver Q18 (2.4Vpp)
CH.2: AUDIO GAIN R65 set to 500mVpp



CH.1: Audio Output - phone jack (2.3Vpp)
CH.2: AUDIO GAIN R65 set to 500mVpp

5. TRANSMITTER STAGES

TXLO Input. +18dBm LO from the Hetrodyne VFO is applied to T4 power splitter. T4 divides the +18dBm LO input in two (-3dB), for +15dBm TXLO output (+18dBm-3dB). The TXLO signal is what drives the transmitter. On an o-scope, the TXLO output is about 4.5Vpp (+16dBm) as shown in **Fig. 5-1**. The LO signal is a fairly clean sine wave except for some slight saturation at the negative peaks - typical of most VFO circuits.

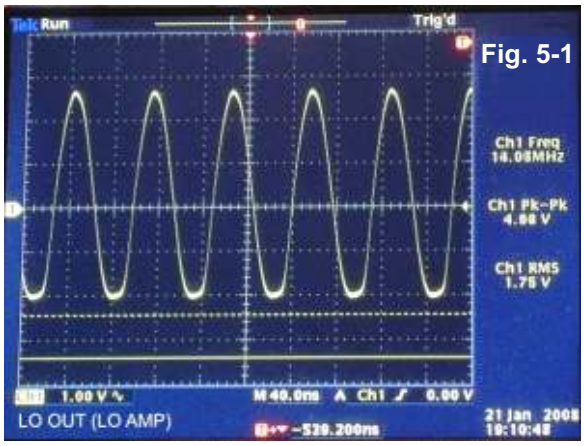
TXLO power is a bit higher than the RXLO due to the resistive termination of TX DRIVE R74. +15dBm is a fair amount of LO power compared to most QRP rigs, simplifying the transmitter circuitry.

The TXLO spectrum is shown in **Fig. 5-2**. Note how the +15dBm LO power measured on the spectrum analyzer (50Ω device) is within 1dB of the same power determined from an o-scope (hi-Z device). A 1-2dB difference from your measurements to those shown is acceptable due to variations between circuits - and instruments.

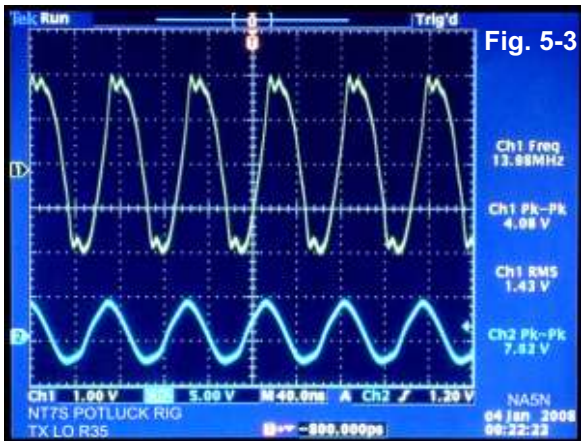
NOTE: *The following tests are based on **key-down transmit**. Ensure you have a dummy load connected to the antenna jack before transmitting, and avoid prolonged periods of key-down longer than 30 seconds (though the PA never gets very hot - a sign of good efficiency).*

TXLO is applied to TX DRIVE adjust R74. For my tests, adjusting R74 for 4Vpp at the wiper (base of Q22) produced exactly 5 watts out (assuming your scope has at least a 20MHz bandwidth).

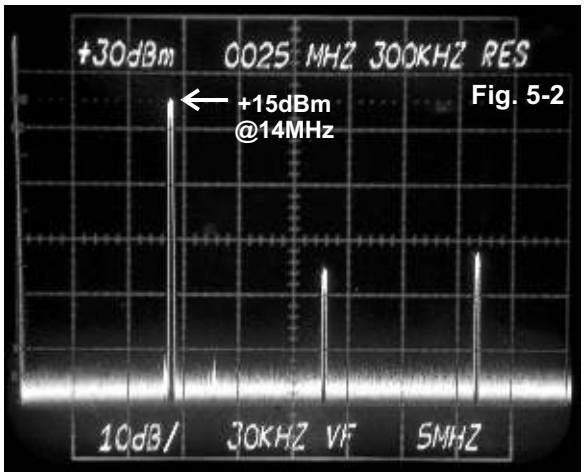
TX Driver Q22. With the TX DRIVE set for 4Vpp drive, this applies about +10dBm to the base of TX Driver Q22 (2N5109). This is shown in **Fig. 5-3** comparing the +18dBm LO input (Ch.2; 7Vpp) to Q22 base (Ch.1; 4Vpp).



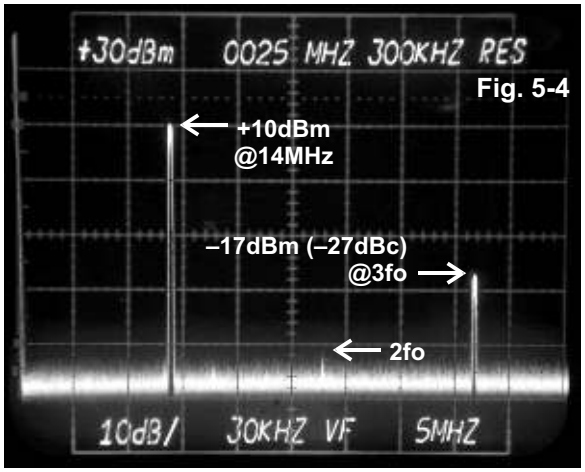
CH.1: LO INPUT AT C29 (4.5Vpp, +16dBm)
CH.2: Not used



CH.1: INPUT TO DRIVER Q22 (4Vpp, +10dBm)
CH.2: TXLO INPUT (7.5Vpp, +18dBm)



TXLO AT T4 Power Splitter (+15dBm)



+10dBm Q22 INPUT (TX DRIVE SET TO 4Vpp)

Note how the Q22 drive signal, **Fig. 5–3**, is no longer a perfect sine wave; the ripples at the negative and positive peaks are signs of harmonic energy (mostly 3rd harmonic). This is unavoidable due to TX DRIVE pot R74 and the input impedance to Q22 changing with different power levels. This is normal and easily filtered out later in the output low pass filter.

The spectrum analyzer shows the harmonic energy at Q22 in **Fig. 5–4**. The 3rd harmonic (3fo) is down about -27dBc, 2fo barely discernable.

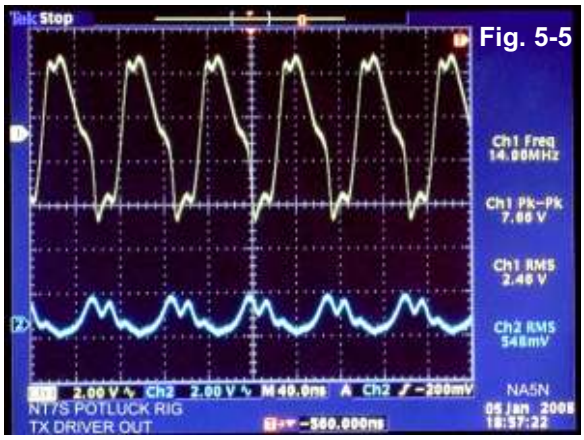
With +10dBm input (4Vpp Q22 base) and +21dBm output (7.6Vpp Q22 collector), TX driver Q22 provides 11dB of power gain. This is more than sufficient to drive the power amplifier (PA). The output of driver Q22 is shown in **Fig. 5–5**.

The +21dBm Q22 driver 50Ω output at T8 passes through T9 to transform the impedance to the PA to about 12Ω. **Fig. 5–6** shows the spectrum at the PA input and the harmonic powers still present.

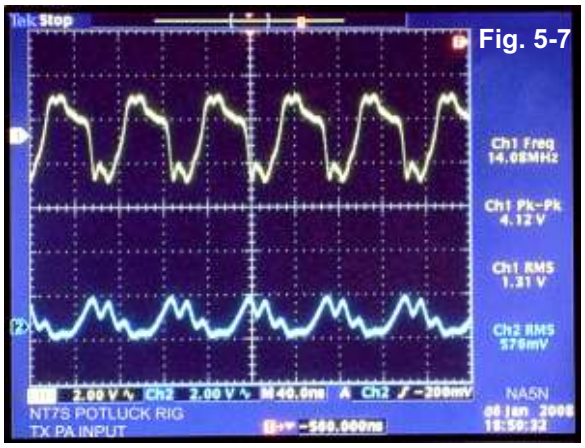
Power Amplifier (PA) Q23. The input to the PA, as seen on an o-scope, is shown in **Fig. 5–7**. Some power is lost through T9, and due to the low impedance input of the PA transistor, such that about 4Vpp (+16dBm) is actually applied.

Fig. 5–8 compares the PA transistor input signal (bottom trace) to the PA output (top trace) at Q23 collector to show the overall gain. The 4Vpp input signal, and the 30Vpp output, clearly shows the 17dB power gain being provided by the PA transistor.

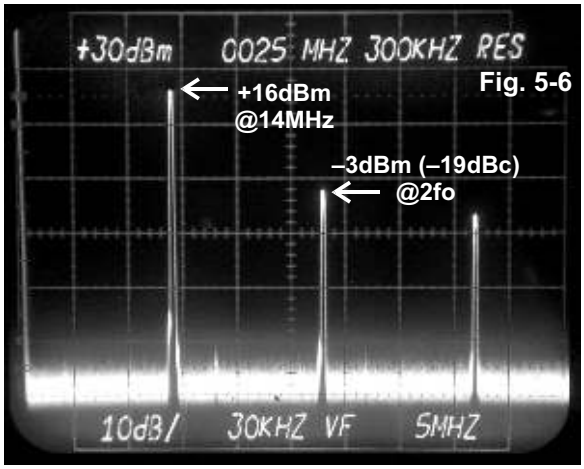
The distorted input signal (Ch. 2) is an artifact of the low impedance drive of the base and the PA input capacitance charging and discharging. The PA collector (Ch.1) shows the amplification of the signal, and how the collector inductance of T9 sustains power to clean up the signal, and elevates the swing from the +12V supply to 30Vpp.



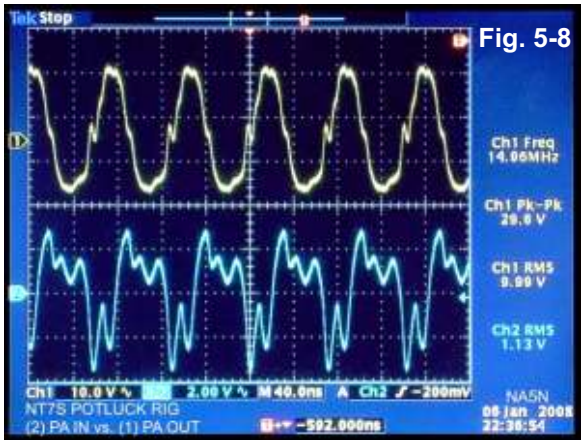
CH.1: Driver Q22 output (7.6Vpp, +21dBm)
CH.2: TXLO input (2Vpp, +10dBm)



CH.1: Q23 PA base drive (4.1Vpp, +16dBm)
CH.2: TXLO input (2Vpp, +10dBm)



Spectrum at Q23 PA base input

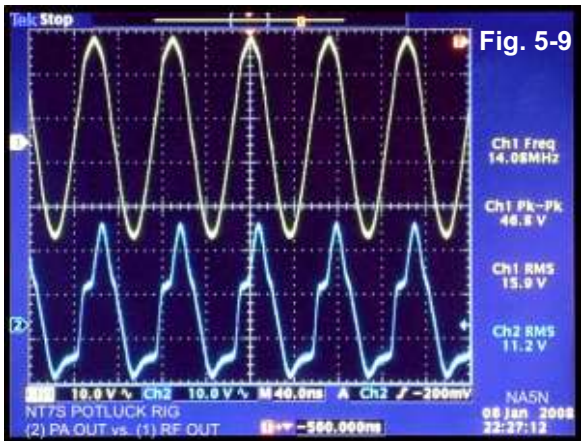


CH.1: Q23 PA collector (30Vpp, +33dBm)
CH.2: Q23 PA base drive (4Vpp, +16dBm)

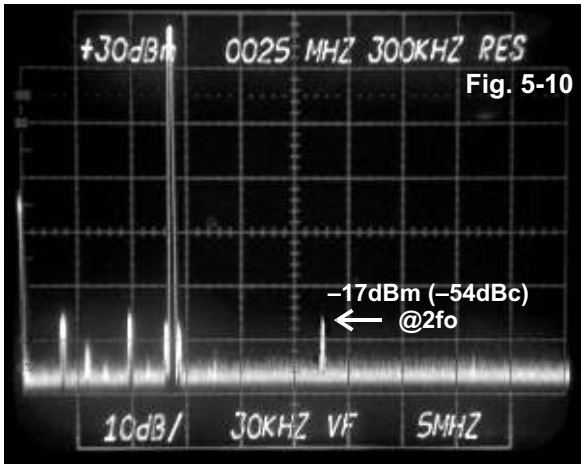
PA Output Impedance. The output impedance of the PA transistor must be transformed to 50Ω to begin the process of matching the transmitter to the antenna. The output impedance of the PA at 5 watts is approximated by the equation:

$$RL = \frac{Vcc^2}{2Po} = \frac{12v^2}{2*5W} = 14\Omega$$

Transformer T9 is a 1:4 transformer; that is, the 14Ω PA output is converted to 56Ω (14Ω x 4), very close to the desired 50Ω. The low pass filter (LPF) network does the rest. Usually this transformer is wound on a T50-43 or similar wideband toroid. Jason uses a binocular core, which yields good efficiency.



CH.1: Antenna RF out (47Vpp, +37dBm=5W)
CH.2: Q23 PA collector (30Vpp, +33dBm)



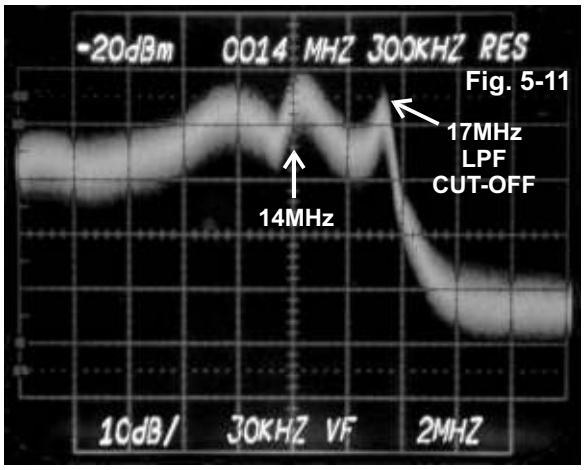
Antenna RF Out spectrum showing +37dBm (5W) 14MHz output and effective attenuation of harmonics. The 2nd harmonic is –17dBm, or 54dB below the carrier (–54dBc). An external 10dB attenuator was used, such that the top +30dBm graticle is actually +40dBm.

Jason uses quite a few bifilar wound transformers to carefully control impedances in both the transmitter and receiver stages.

TX Low Pass Filter (LPF) The main job of the TX low pass filter is to attenuate harmonics and other unwanted power above the desired fundamental. In this case, the fundamental is the 14MHz transmit frequency; the cut-off frequency is set slightly above that – in this case 17MHz. Thus, frequencies above 17MHz are attenuated.

Fig. 5–9 shows the PA output signal (bottom trace) and the signal at the antenna jack (top trace). The antenna output is 46Vpp, or a nice, clean 5W. The nice clean sinewave also indicates there is very little harmonic power, as verified by the output spectrum shown in **Fig. 5–10**. The 2nd harmonic is 54dB below the carrier (-54dBc), far exceeding the -36dBc requirement of the FCC. The 3rd harmonic is barely discernable.

Fig. 5–11 is the noise sweep of the LPF. The peak at 14MHz is due to the 14MHz peaking circuit L11-C77. The Q>2 of the LPF causes the characteristic peak at the cut-off frequency of the filter, 17MHz in this case, followed by the obvious sharp roll-off of the output filter.



Noise sweep of the output low pass filter

Whether you have an oscilloscope or not, hopefully these waveforms will assist in demonstrating how the circuits in the QRP-L.org Group Project rig works.

Now, disconnect the dummy load and make some contacts :-) GL building and operating yours.

72, Paul NA5N (na5n@zianet.com)

6. APPENDIX

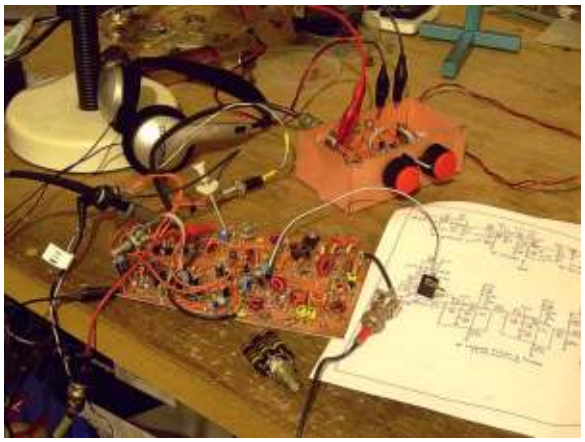
dBm – Volts – Power Conversion Chart

dBm	Volts rms	Volts p-p	Power
+37	16v	45v	5.0W
+35	13v	37v	3.3W
+30	7v	20v	1.0W
+25	4v	11v	320mW
+20	2.3v	6.5v	100mW
+15	1.3v	3.7v	32mW
+10	0.7v	2.0v	10mW
+ 5	0.4v	1.1v	3mW
0dBm	.23v	.65v	1mW
- 5	.13v	.37v	320uW
-10	.07v	.20v	100uW
-15	.04v	.11v	32uW
-20	23mV	65mV	10uW
-25	13mV	37mV	3uW
-30	7mV	20mV	1uW
-35	4mV	11mV	.3uW
-40	2mV	6mV	.1uW

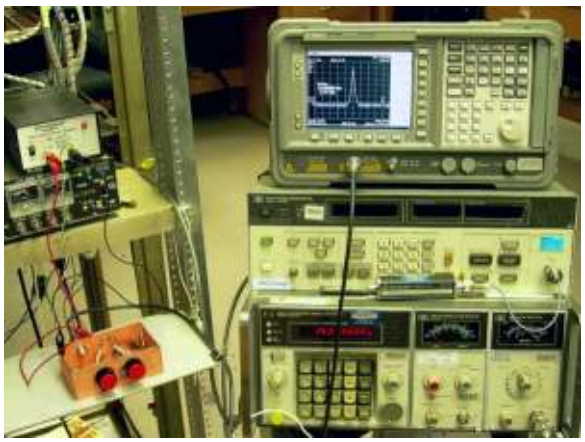
Measure peak-peak voltage on an o-scope
Convert Vp-p to dBm or watts from chart

On a calculator:
dBm = 20log(1.59 x Vpp)

Example: *What is 0.5Vpp on a scope in dBm?*
dBm = 20log(1.59 x 0.5Vpp) = –2dBm
What is 1.5Vpp on a scope in dBm?
dBm = 20log(1.59 x 1.5Vpp) = +7.5dBm



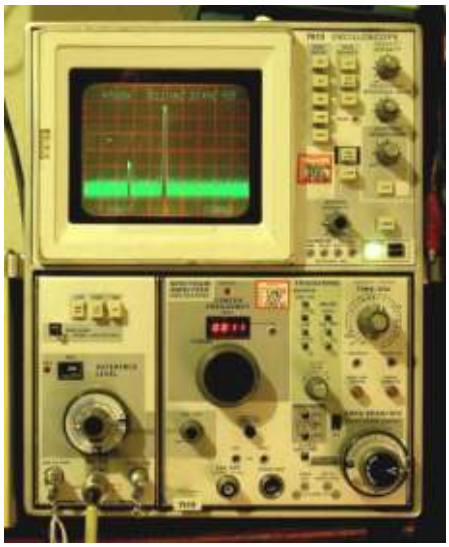
The first prototype of the QRP–L.org group project rig and the hetrodyne VFO. The QRP rig was designed and built by Jason Milldrum, NT7S.



Some of the test equipment at the VLA observatory for testing the low band receiver upconverters (for 74, 196 and 327MHz receivers). The Agilent E4406 spectrum analyzer was used to test the hetrodyne VFO for spectral purity and phase noise.



Testing Jason's prototype rig. The new Tek TDS3032 scope was borrowed for the waveform photos. The rest of the junk is is part of the NA5N QRP workbench.



A closer view of the Tektronix 7L13 spectrum analyzer, circa. 1970-1980s. This is one of the popular spectrum analyzers often found on the used market.

"HappyHolidays TRX"
A four band VXO tuned
1 watt QRP CW transceiver

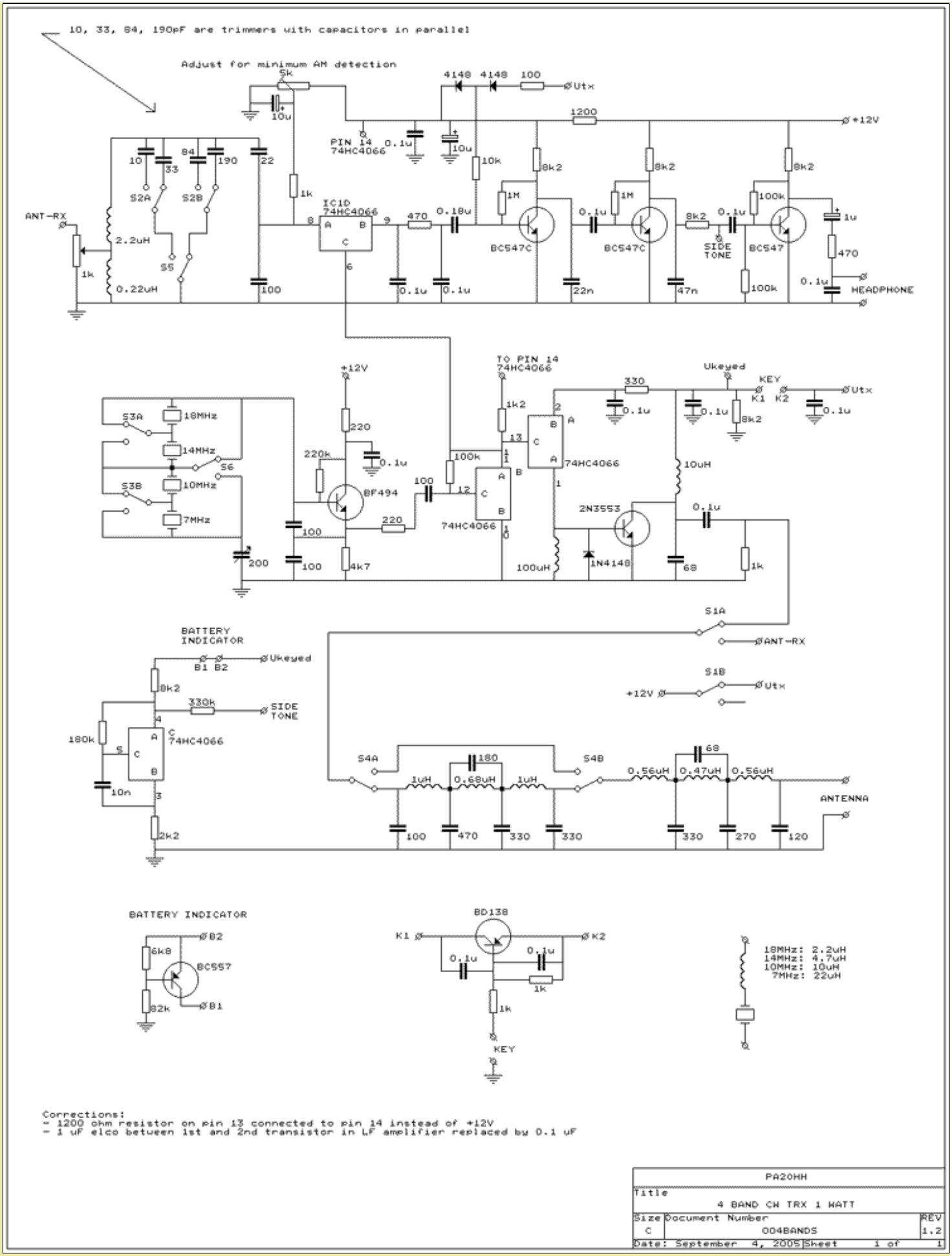
KLIK HIER VOOR DE NEDERLANDSE VERSIE



A simple, solid rig for outdoor use during Holidays.
More is possible with this solid QRP rig than you should expect.
Just try it and do not give up soon!

QRP during Holidays
A couple of years ago I made a 2 band 1 watt VXO tuned transceiver (40-20m) and took it with me on holidays to the northern countries of Europe.
When camping in the middle of nowhere, I did have daily QSO's with two amateurs in the Netherlands.
The antenna was an inverted V dipole, the centre approx. 4 meters above ground. I expected that it was almost impossible to make QSO's with such low power and such a simple rig. But it was quite easy to make a lot of QSO's and that was a great experience.

The "HappyHolidays" is a 4 band 1 watt VXO controlled transceiver, with similar performance but with more recent components and better suppression of AM detection and also intended for Holiday use. It was an experiment to make a 4 bander. But now I would have preferred a 2 or 1 band transceiver, there are so many switches on the 4 band transceiver.



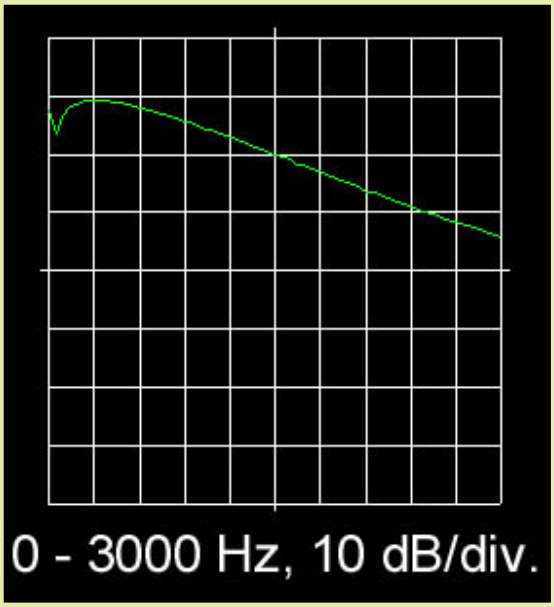
Circuit diagram

Circuit diagram
R1 is the 1200 ohm resistor just below the pin Utx
big diagram

RF preselector and attenuator
The RF attenuator is a potentiometer of 1k ohm. An RF attenuator is always very useful to prevent overload of the first stages of a receiver. Most receivers perform better on 40 and 30 meters with some RF attenuation. Here it is also the only volume control.
The capacitors of 10, 33, 84, and 190 pF are approximate values and are combinations of trimmers and capacitors in parallel. Adjust the trimmers for maximum sensitivity.

Mixer
The mixer is one C-mos switch of the 74HC4066 (Do not use a HCT!!!). It works perfect!!!
Adjust the 5k potmeter for minimum AM detection of strong broadcast stations. If you do not have an AM signal available for adjustment, set it to centre position.

LF amplifier
Just a simple 3 transistor amplifier. The first transistor is muted during TX via the 10k resistor. The LF amplifier is optimized for CW reception with a low LF beat tone. The selectivity of the ear is very good for low audio tones up to 600 - 800 Hz, a CW filter is not really necessary.
Select the value of R1 (1200 ohm) so that in receive mode, the supply voltage of the 74HC4066 (pin 14) is approximately 5 V.



The LF amplifier is optimized for CW
but it is not a very narrow CW filter.

VXO
The VXO is a BF494 transistor, buffered via a C-mos switch. To give you an impression about the tuning ranges related to the crystal frequencies, here the values of my version without and with the optional inductors in series with the crystals for an increased tuning range.

Tuning ranges without the optional series inductors		
Crystal Frequency (kHz)	Minimum Frequency (kHz)	Maximum Frequency (kHz)
7025	7024.3	7026.2

10125	10123.7	10126.5
14050	14048.2	14051.9
18080	18076.6	18080.4

Tuning ranges with the optional series inductors		
Crystal Frequency (kHz)	Minimum Frequency (kHz)	Maximum Frequency (kHz)
7025	7021.1	7023.8
10125	10118.4	10123.0
14050	14039.9	14045.9
18080	18070.6	18076.4

Transmitter part
The VXO signal is buffered by a C-mos switch and amplified to 1 watt by a transistor 2N3553 or as I did, 2 transistors 2N4427 in parallel. The 1k ohm resistor makes the amplifier more stable when mismatches occur. The 0.68 uH / 180 pF and 0.47 uH / 68 pF are tuned to the second harmonic of 7 resp. 14 MHz for extra suppression.

Options

- Battery indicator (no sidetone if battery low)
- Key connected to ground with the possibility to use electronic keys
- Enhanced tuning range of the VXO with inductors in series with the crystals.



Foldable headphones, a simple key and batteries.

How to work with the Happy Holidays

During transmission the VXO frequency has to be identical to that of the other station. When receiving, it needs to have an offset of 300-800 Hz, depending on the beat tone frequency you want to listen to. Therefore, it is necessary to tune the VXO approximately to zero beat with the other station just before the end of its transmission. When receiving, tune the VXO to the desired offset. In receive mode, tune the VXO offset frequency to the other side of the received signal if there is less interference on that side. After a few QSO's you will be completely used to how you have to operate the rig.



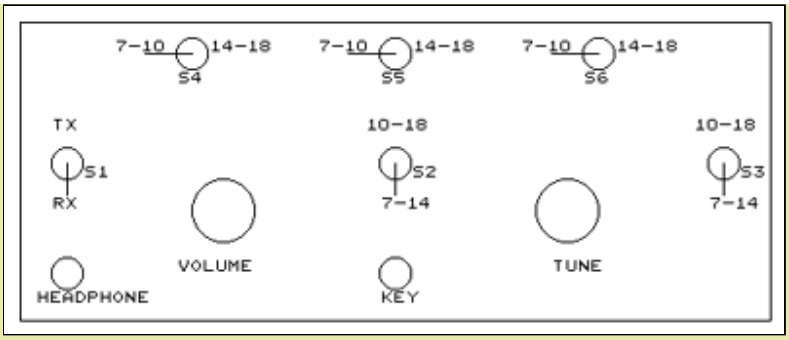
Portable width the "HappyHolidays TRX"!

Notes

Built via the ugly method (dead bug method). Parts are soldered at both sides of he double sided unetched print.
Inductances are commercially available types looking like big resistors.
Do not use a HCT type but a HC type!

Performance

Sensitivity: 0.6 uV signals are readable
3rd intercept: more than 20 dBm
Spurious responses of the receiver: Better than -90 dB
RX current: 10 mA
Transmit power: 0.5 W at 9 V; 1 W at 12 V; 1.5 W at 13.5 V
Harmonic suppression: below 30 MHz: 43 dBc, above 30 MHz: 60 dBc



Position of switches and other controls

Position of switches and other controls
Place the switches so that you will have a very short wiring!
S1 is the TX/RX switch, five other switches (S2 to S6) are used for bandswitching instead of one big complex switch.
Place S1+S4 near the lo-pass filter, S2+S5 near the preselector filter and S3+S6 near the VXO.
S1 should be near the lo-pass filter and also near the final RF amplifier.
The Variable Capacitor is placed very close to the VXO.
The RF potentiometer close to the TX/RX switch S1.
The antenna connector of course close to the lo-pass filter output.
The positions of the headphones connector and key input are not critical.

50 Hz or 100 Hz hum of a direct conversion receiver
The rig is designed for use with a battery supply.
When you use a power supply connected to the mains, it is possible that you will hear some 50 Hz / 100 Hz hum due to Local Oscillator leakage from the mixer to the antenna. This depends on the antenna, frequency band and power supply you are using. A lot of Direct Conversion receivers have this problem.
To overcome this problem you can add the RF preamplifier as is given here below at the 21 MHz version. Increase the 270 ohm emitter resistor if the sensitivity is too high.
Not all preamplifiers do suppress the Local Oscillator leakage from the mixer to the antenna. The first version of the preamplifier without the second transistor in the collector did not suppress the LO leakage and also an emitter follower was not usable.

PHOTOGRAPHS



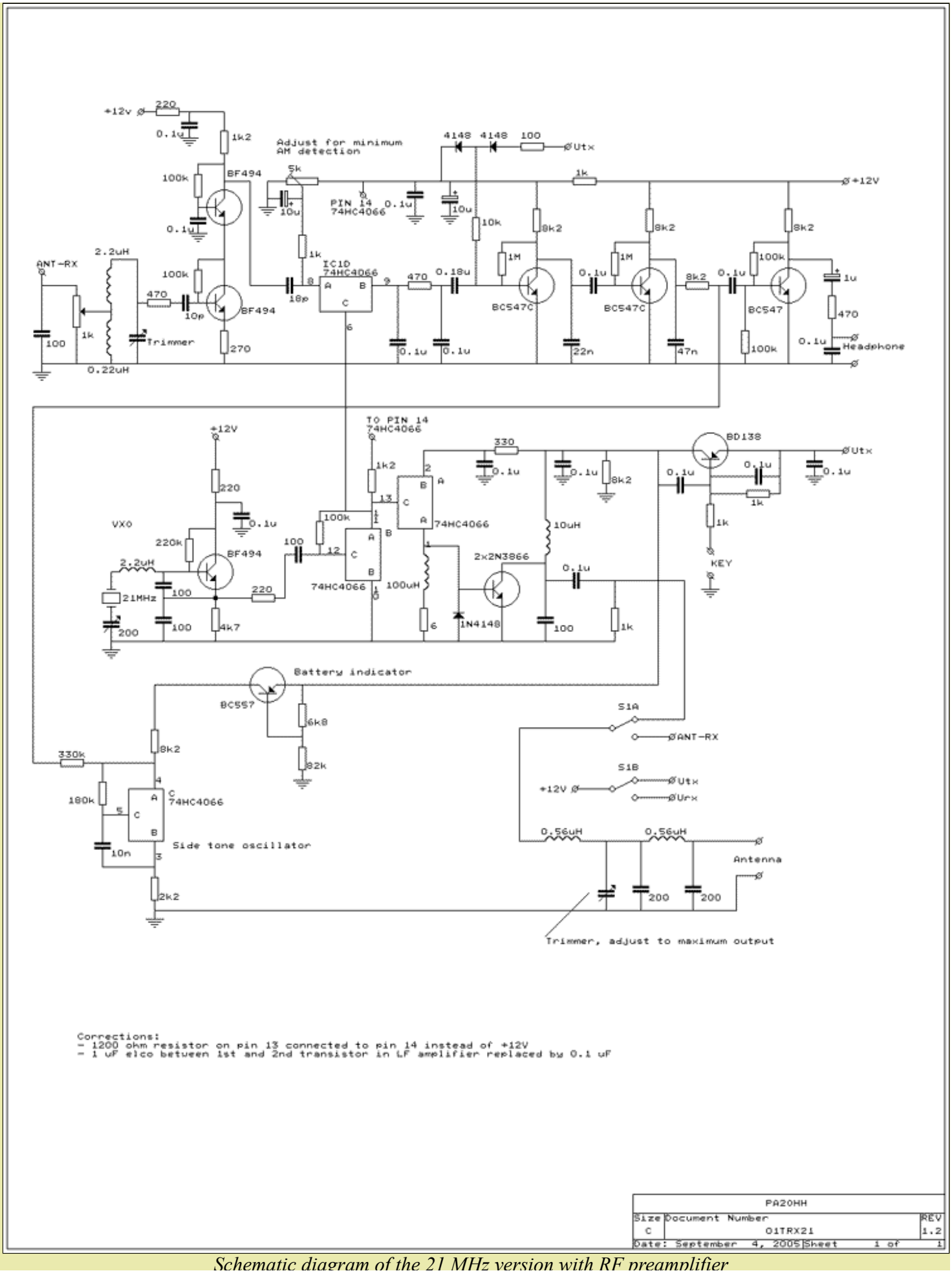
Inside the box. The VXO is screened from the rest of the circuit by a verical piece of PCB.



Both sides of the unetched PCB are fitted with components

---

21 MHz version with RF preamplifier



Corrections:
- 1200 ohm resistor on pin 13 connected to pin 14 instead of +12V
- 1 uF elco between 1st and 2nd transistor in LF amplifier replaced by 0.1 uF

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Size C	Document Number 01TRX21	REV 1.2
Date: September 4, 2005	Sheet 1 of 1	

Schematic diagram of the 21 MHz version with RF preamplifier

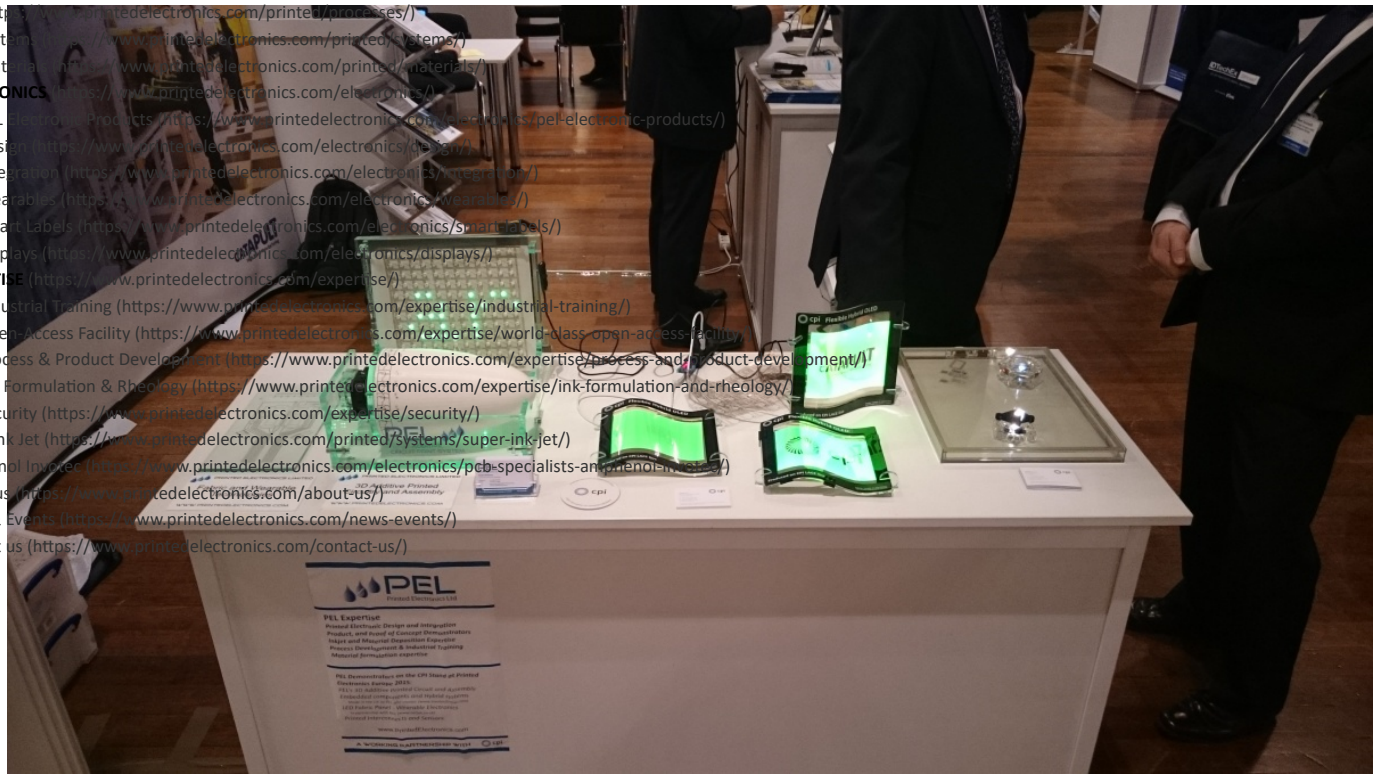
Schematic diagram of the 21 MHz version with RF preamplifier.

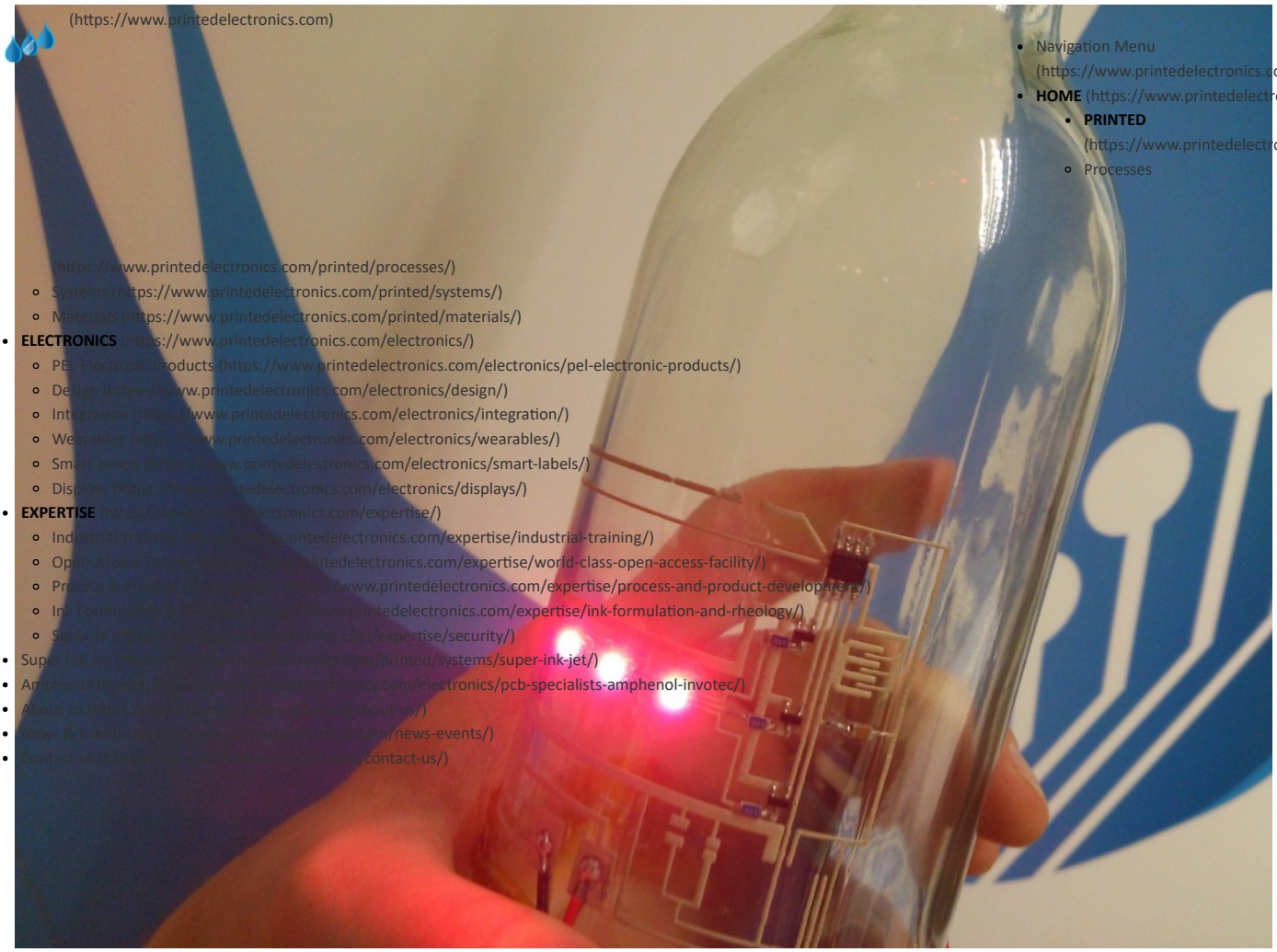
big diagram

Why an RF preamplifier

The RF amplifier improves the sensitivity: 0.3 uV signals are readable.
But that is not the only reason to add the amplifier. A second, even more important reason is that it attenuates the Local Oscillator leakage from the mixer to the antenna input by 20 dB. This oscillator leakage may cause problems if you use a power supply instead of batteries, mostly on the higher bands.
A loud 50 or 100 Hz audio tone is the result of too much Local Oscillator leakage. Without the amplifier, the 21 MHz version had this problem. With the amplifier there was no hum anymore and the sensitivity was very good.

BACK TO INDEX PA2OHH


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Printed Electronic Design and Integration
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Inkjet and Maskless Deposition Expertise
Process Development & Industrial Training
Material formulation expertise
PEL Demonstrators on the CPI Stand at Printed Electronics Europe 2015:
cpi



This is a fully functional circuit with multiple components that was created to demonstrate our ability to create circuits on 3D objects.



A.M. RADIO DESIGN LAB

BEFORE YOU BEGIN

PREREQUISITE LABS

- Passive and Active Filters Lab
- Fourier Transforms Lab
- Introduction to Oscilloscope
- Introduction to Arbitrary/Function Generator

EXPECTED KNOWLEDGE

- Laplace transform circuit analysis
- Analog filters
- Op-Amp applications

EQUIPMENT

- TDS3034B Series Digital Phosphor Oscilloscope
- AFG3000 Series Arbitrary/Function Generator
- Programmable Power Supply
- Speaker Switch Box
- Computer Speakers

MATERIALS

- Inductor Bobbin and Wire
- Variable Capacitor (8.5 – 120 pF)
- 2 x 741 Op Amps
- Germanium Diode
- Condenser Microphone
- 20 feet of wire
- Solderless Breadboard

OBJECTIVES

After completing this lab you should know how to:

- Modulate an A.M. signal
- Demodulate an A.M. signal
- Build a simple A.M. receiver

INTRODUCTION

AMPLITUDE MODULATION

Radio stations transmit electromagnetic waves at different frequencies. When you turn the tuning dial on your car radio, you change the frequency that your radio receives. For example, when

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your radio receives an FM station at 107.5 MHz, it is tuned to receive only signals with frequency content that is close to 107.5 MHz.

You can not hear electromagnetic waves and, even if you could, you can not hear frequencies as high as 107.5 MHz. Your can only hear audible frequencies up to about 20 kHz. Radio transmitters "mix" the sound waves into the 107.5 MHz signal and convert it to an electromagnetic wave. This process of mixing two signals at different frequencies is called modulation. Your car radio receives the electromagnetic waves, converts them to electrical signals, separates the audio and radio signals, and sends the audio signal to your speakers.

Radios use one of two methods to "mix" audio frequency sounds into a radio signal. They are frequency modulation (F.M.) and amplitude modulation (A.M.). The scope of this lab is limited to amplitude modulation.

A.M. modulation changes the amplitude of a high frequency, sinusoidal electromagnetic wave by an amount proportional to the amplitude of the sound wave. Figure 1 shows a radio signal with no modulation.

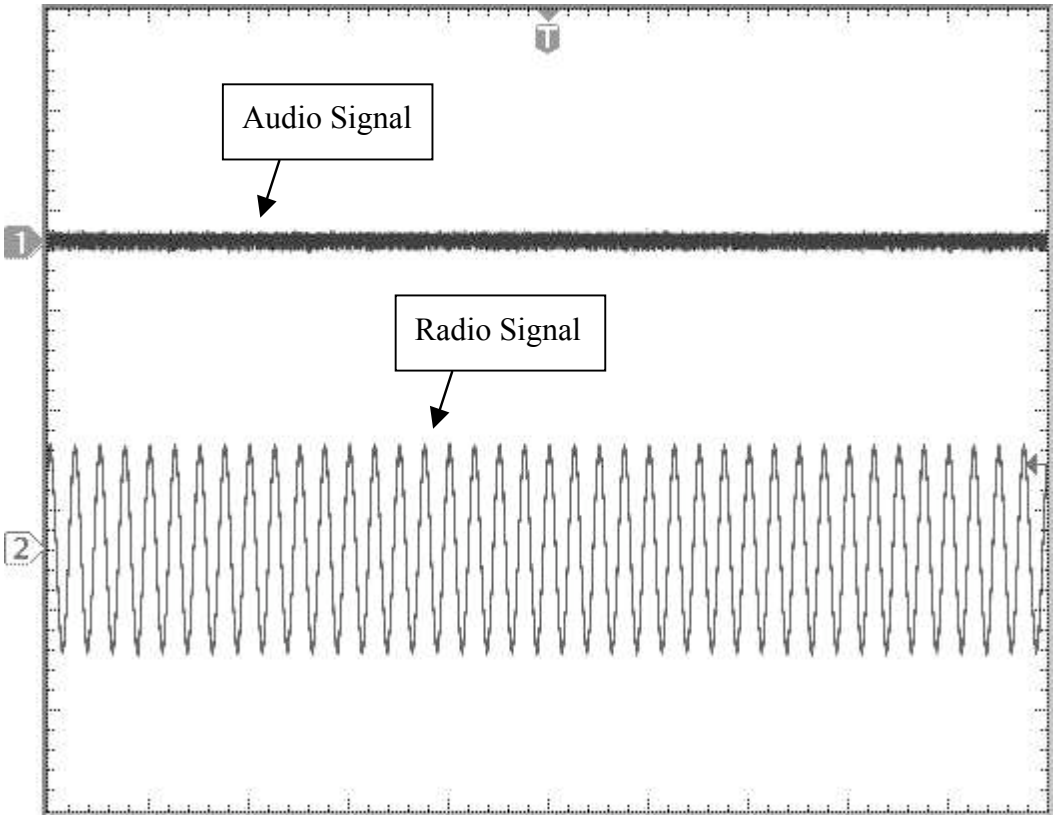


Figure 1: Radio wave with no modulaton

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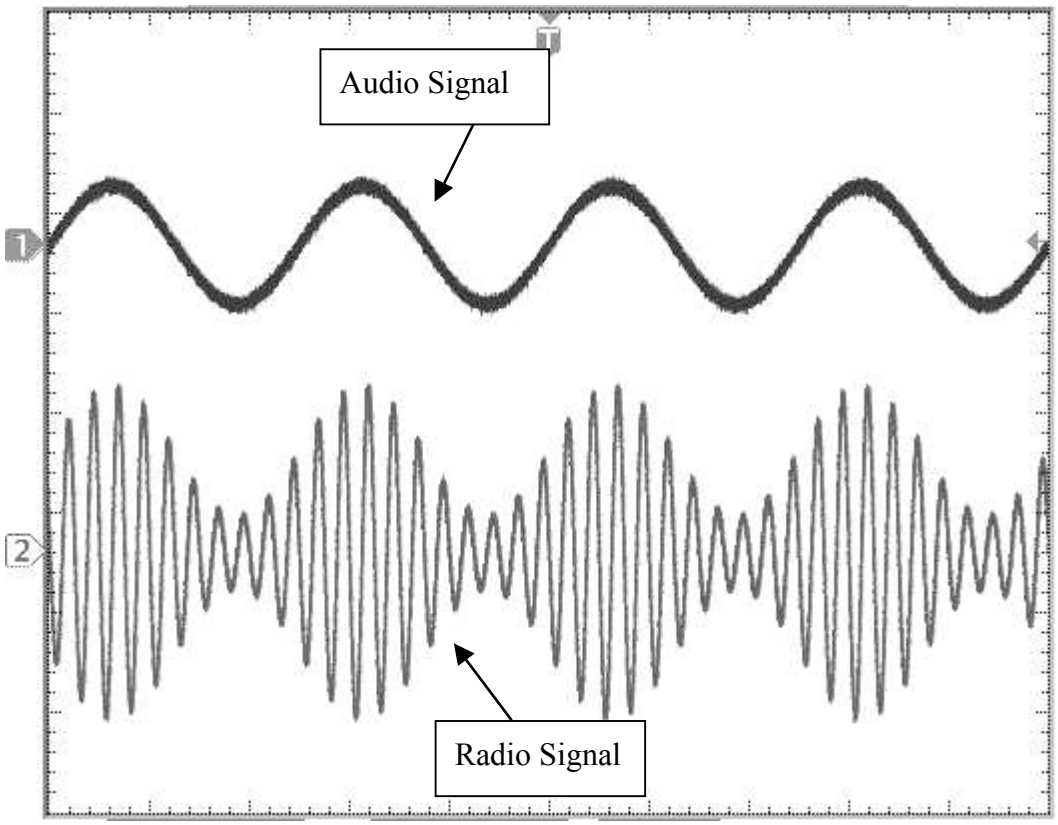


Figure 2: Radio wave with amplitude modulation

Figure 2 shows a radio signal with amplitude modulation. The amplitude of the radio wave follows the amplitude of the sound wave as in Figure 2.

A.M. DEMODULATION

In this lab, we will be using a diode to convert the received signal into an audio signal. This process is called A.M. demodulation.

A diode is a device that only allows current flow in one direction. If we apply an AC signal to one end of a diode, as in Figure 3, we will only see the positive portion of that signal at Vout.

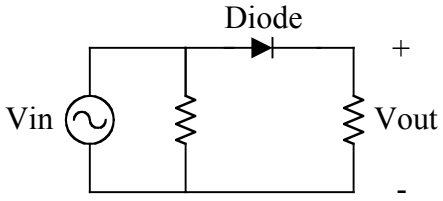


Figure 3: Diode Demonstration Circuit

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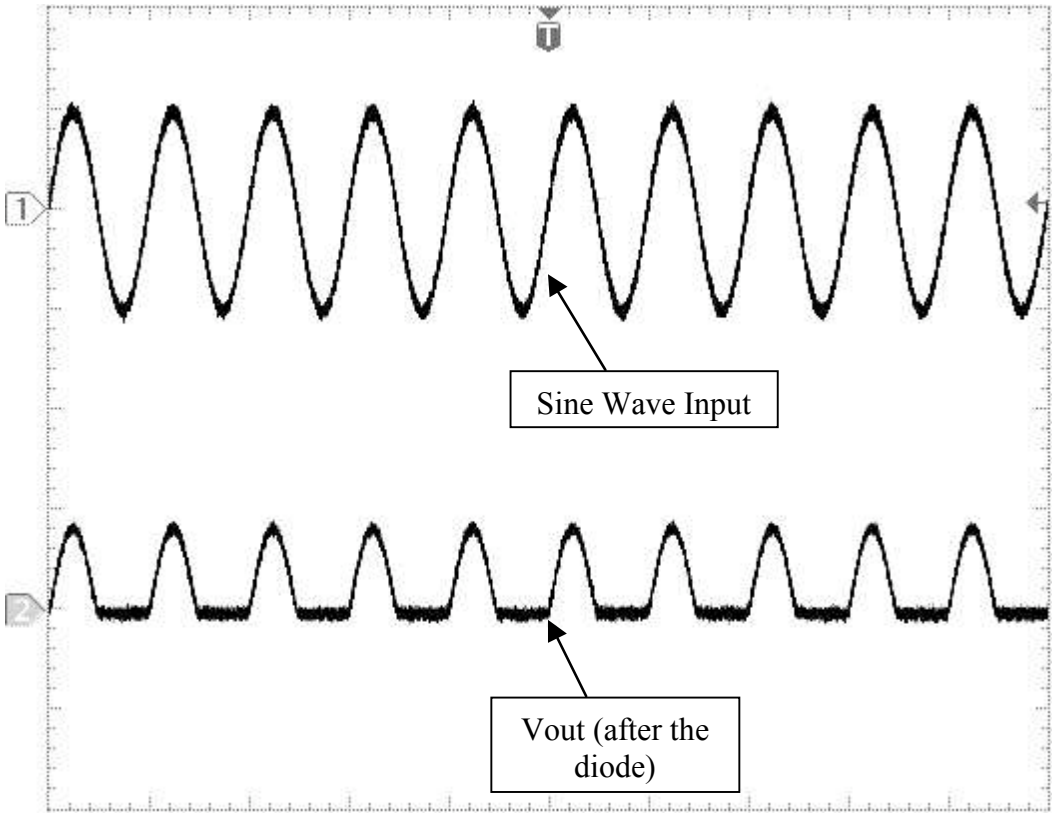


Figure 4: Rectified Sine Wave

As you can see in Figure 4, the diode removes the negative portion of the incoming signal. This is called half wave rectification. The lower waveform in Figure 4 is said to be half wave rectified.

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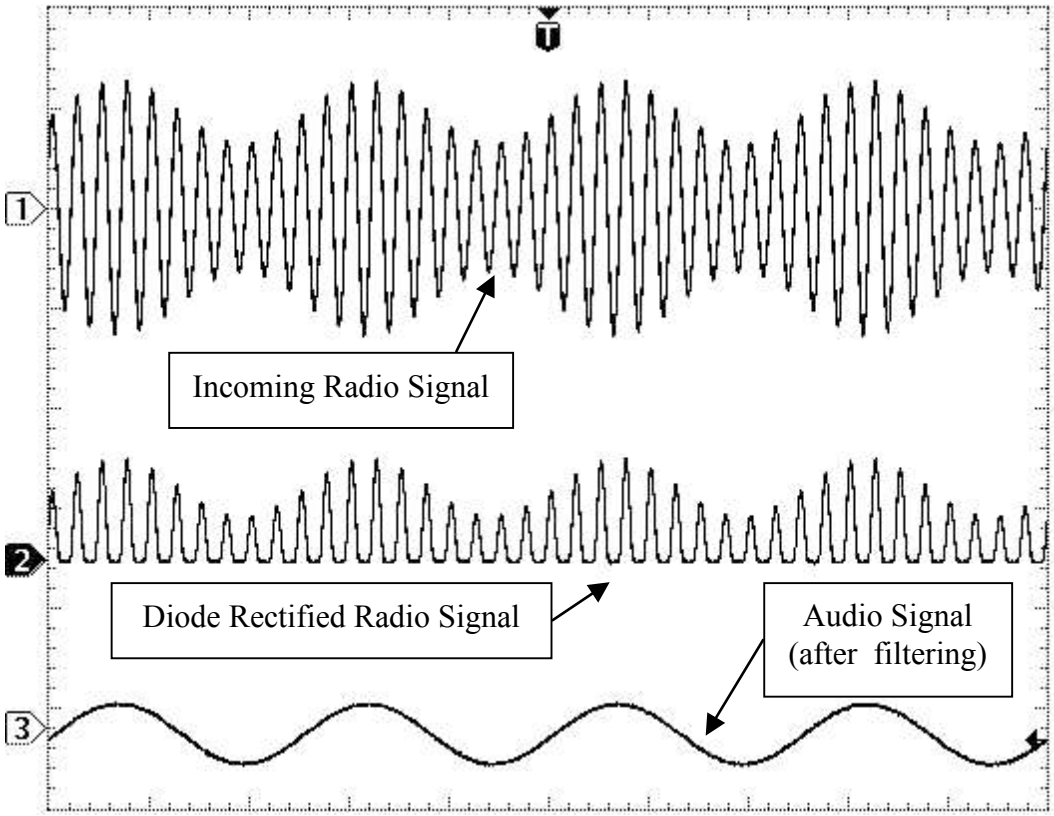


Figure 5: A.M. Radio Wave Rectification

Diode rectification is a simple way to help demodulate an A.M. radio signal. Figure 5 shows how an incoming radio wave is effectively cut in half when it passes through a diode. Since the current can only flow in one direction we will only see positive voltages. The remaining signal is low pass filtered to remove the radio frequency, leaving only the low-frequency audio signal.

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PRELAB

AUDIO SIGNAL GENERATION

To generate our audio signal, we will use a condenser microphone and an op-amp as shown in Figure 6. The condenser microphone needs a small DC current to make it operate correctly. This current is controlled by R3.

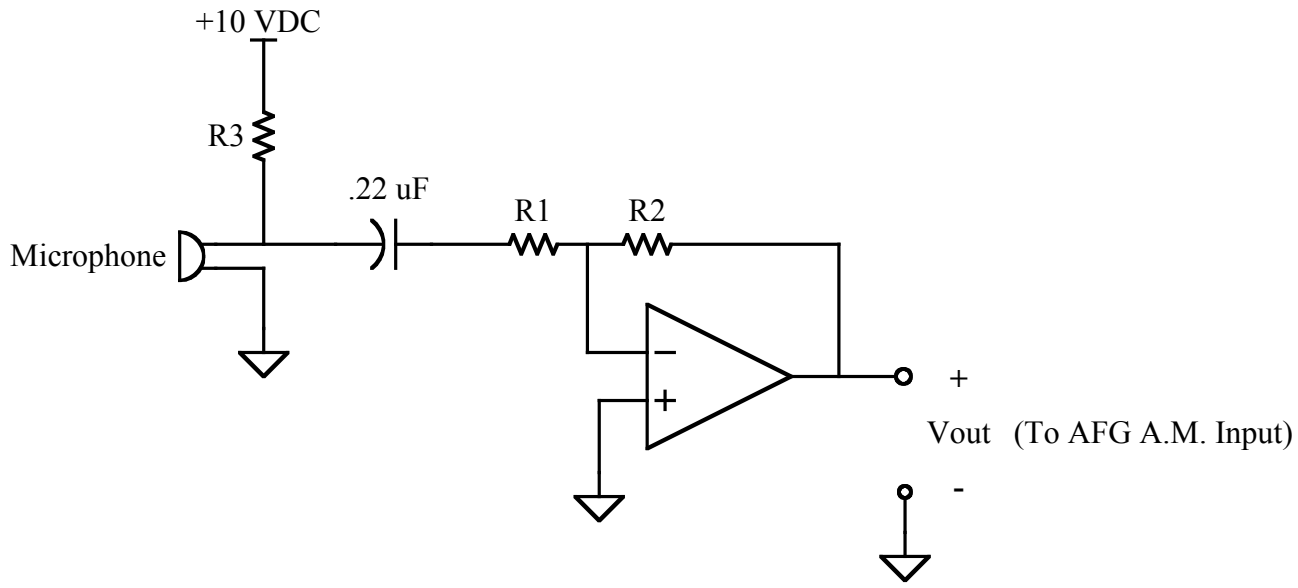


Figure 6: Microphone and Amplifier Circuit

In this configuration, the microphone acts like a sound controlled variable resistor. The sound waves that the microphone picks up control the resistance of the microphone. The changing resistance causes the voltage on the microphone's ungrounded pin to change according to the amplitude of the sound wave on the microphone. This produces an audio frequency AC voltage signal at the microphone's ungrounded pin. The audio AC signal then passes through the large capacitor to block all DC voltages, and is amplified by the inverting amplifier circuit.

Answer Questions 1 – 2.

A.M. RADIO TRANSMISSION

To transmit A.M. signals, we will be using the Arbitrary/Function Generator (AFG). The AFG has a modulation input, and it will amplitude modulate any signal. The only remaining component is the antenna. Radio signals are waves with a specific frequency and wavelength. For an antenna to efficiently broadcast radio waves, it has to be a specific length. According to wave theory, $v = f\lambda$ where v is the velocity of the wave (in our case, 300 M m/s), f is frequency of the wave (in hertz), and λ is the wavelength (in meters). An efficient antenna has a length

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equal to half of a wavelength. For a 1 MHz wave ($\lambda = \frac{v}{f}, \lambda = \frac{300*10^6}{1*10^6}$, λ=300 meters) an efficient antenna would be 150 meters long.

Answer Question 3.

Other slightly less efficient antennas are λ/4 and λ/8 meters long. We are not concerned with making the most efficient antenna, so any antenna length that is 3 meters or longer will work fine. The antenna will be connected to the positive terminal of Channel 1 output of the AFG.

How an Antenna Works

Charged particles emit radiation when they are accelerated and radio waves are one type of radiation. The AC voltage from your AFG forces electrons into and out of the antenna. This AC voltage accelerates the electrons and causes the electrons to emit radio waves that travel perpendicular to the broadcasting antenna. Therefore, it is best to set up you transmitting antenna so it is oriented parallel to your receiving antenna.

IS THIS LEGAL?

In radio talk, a "band" is a group of frequencies that are all used for the same purpose. The A.M. band on your radio starts at 500 kHz and ends at 1800 kHz. Commercial radio stations use these frequencies. Usually, the U.S. Government requires a person or company to obtain a license before they can transmit on any frequency. However, the government does make some exceptions. Anyone can transmit on the A.M. band as long as their transmissions do not cause any harmful interference to existing stations and as long as their transmissions are not too powerful. The small amounts of power that are used in this experiment are within the legal limits.

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A.M. RADIO RECEIVER

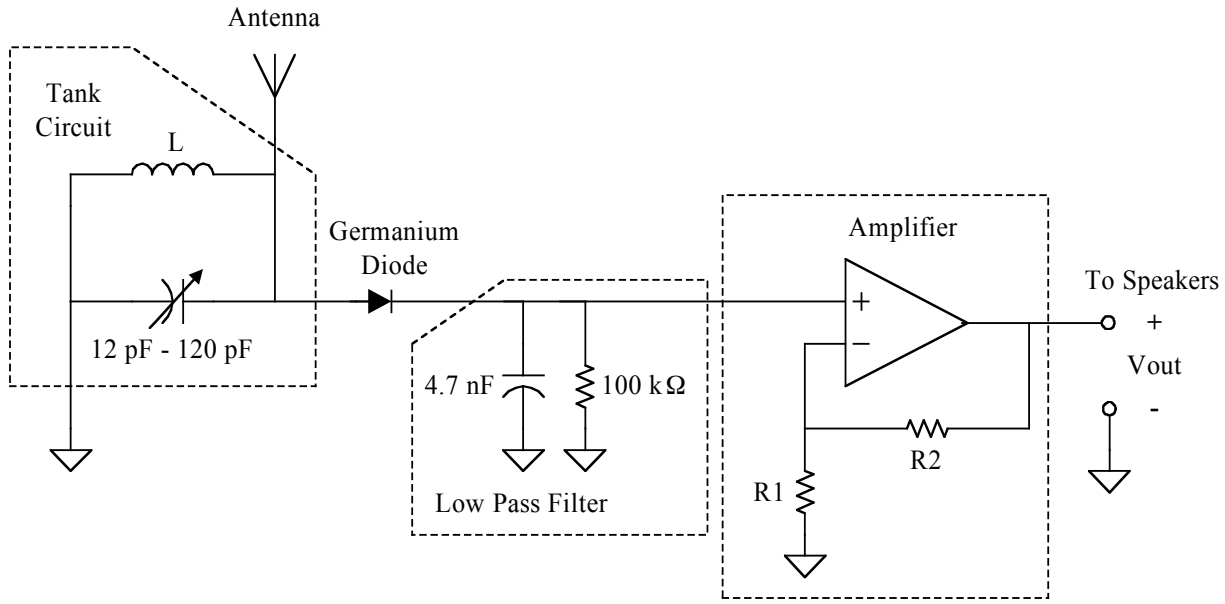


Figure 7: Receiver Circuit

Figure 7 shows the circuit you will build for your radio receiver. This circuit consists of four basic sections: a "tank circuit", a diode, a low pass filter, and a non-inverting amplifier.

The inductor-capacitor parallel combination is commonly called a tank circuit. The tank circuit is a band pass filter with a fairly high Q value. To analyze the tank circuit, we can model the antenna as a sinusoidal current source, as in Figure 8. For this circuit, $\frac{V_o(s)}{I_s(s)} = H(s)$.

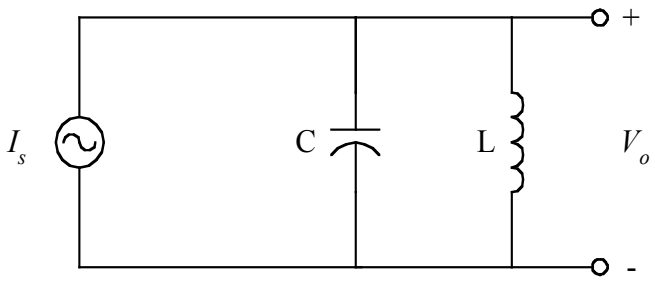


Figure 8: Tank Circuit Analysis

Answer Questions 4 – 5.

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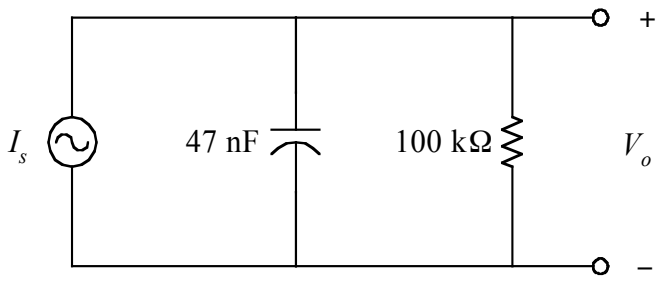


Figure 9: Low Pass Filter Analysis

The capacitor-resistor parallel combination in the receiver circuit is acting as a low pass filter. The current through the diode is acting as the current source in this case.

Answer Question 6.

The op-amp in the receiver circuit is acting as a non-inverting amplifier. We will need a gain greater than 50 to amplify our audio signal enough for us to hear the received signal in the speakers.

Answer Question 7.

BUILDING THE RECIEVER

Your teaching assistant will assign you one of the following frequencies:

1 MHz

1.15 MHz

1.4 MHz

1.8 MHz

2.5 MHz

You will be sharing the frequency with one other group in your lab section.

Answer Question 8.

Unfortunately, factors including parasitic capacitance and resistance change the value you actually need for your inductor. Wrap your inductor bobbin with 150 wraps. **Do not** use the ceramic core to increase the inductance. The ceramic core is intended for use only at low frequencies (<10 kHz). If you use the core, it will greatly decrease the Q value of your tank circuit, making it unsuitable for tuning your radio. You will need to use wire-wrapping wire (AWG 30 or smaller). Connect the inductor and capacitor as in Figure 10.

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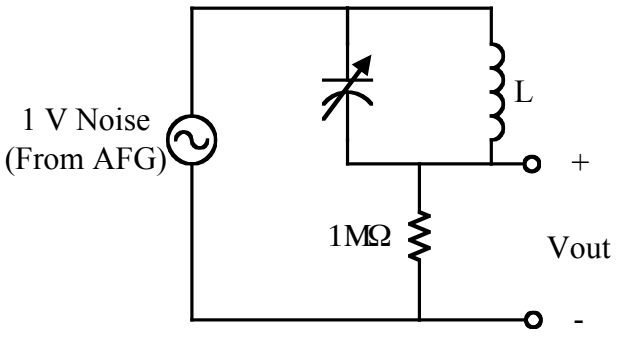


Figure 10: Tank Test Circuit

Change the function on the AFG to Noise and the amplitude to 1 V. At this setting, the AFG will produce white noise that you will feed through your tank circuit. Perform an FFT analysis on the voltage across the 1 MΩ resistor. Set Channel 1 to 100 μs per division and set the FFT to 500 kHz per division. For best results, you will need to have your probe set on 1X and the Channel 1 impedance on the Scope set to 1 MΩ. You should see something like Figure 11 when you have everything set correctly.

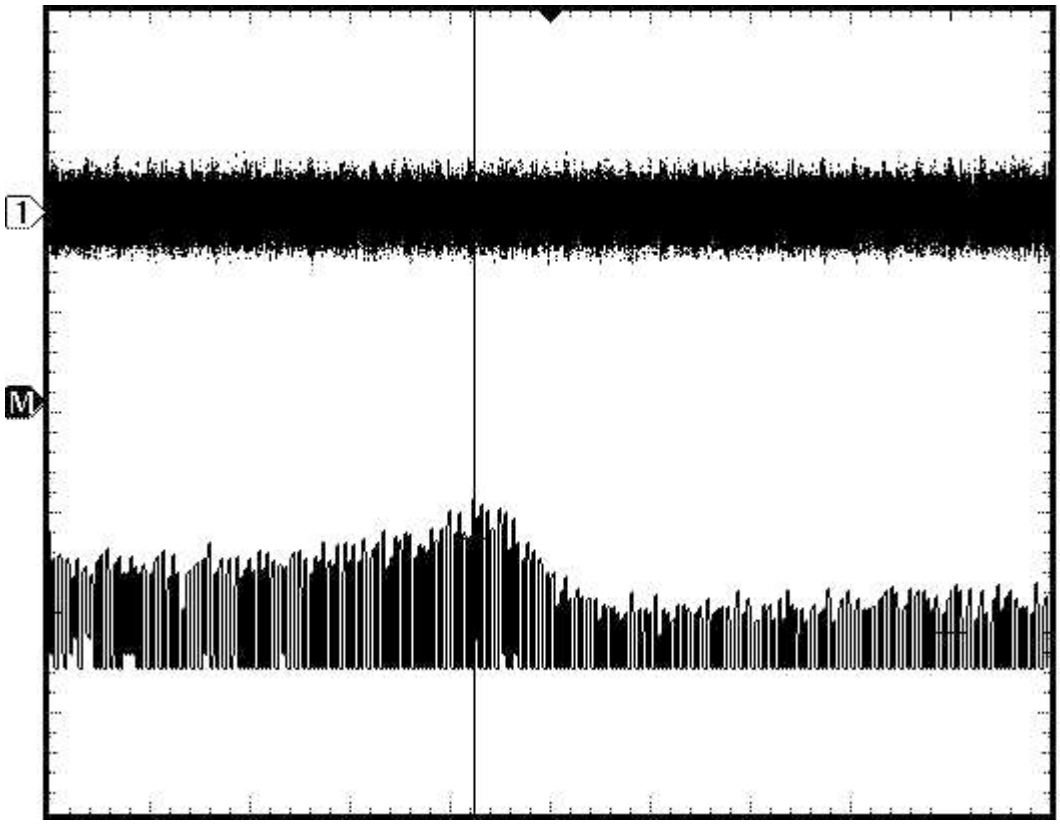


Figure 11: FFT of Noise through Tank Circuit

Figure 11 shows an oscilloscope with Channel 1 activated, and the math plot set to FFT. The bump on the FFT plot corresponds to the resonate frequency of the tank circuit. If you were

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using this circuit to tune in a radio station, the station you would be hearing would be the one transmitting on frequency corresponding to the maximum in your FFT plot. As you adjust your capacitor, you will see the bump on your FFT move left and right. If you do not see this, you are looking at the wrong bump on the FFT. The correct bump will probably be between 100 kHz and 5 MHz.

Answer Questions 9 – 10.

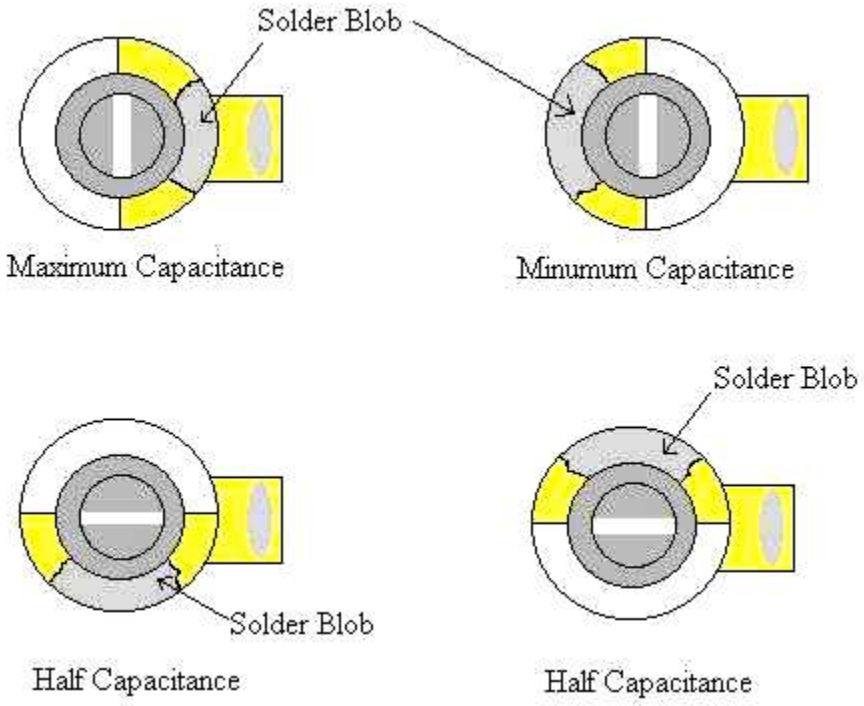


Figure 12: Variable Capacitance Adjustment

Set your capacitor to half capacitance as in Figure 12. You will need to adjust your inductor so that your circuit resonates at the frequency assigned to you when the capacitor is set near its halfway point. If your inductor is too small, the frequency will be too high. You will need to increase the number of wraps on your inductor. If your frequency is too low, you will need to decrease the number of wraps on your inductor.

When you actually combine this tank circuit with the rest of your radio, the tunable frequency range will decrease somewhat due to parasitic capacitance in your solderless breadboard. The frequency assigned to you should still be within your tunable range.

Connect the Receiver Circuit in Figure 7. Use a 10-foot piece of wire for the antenna. Connect the output of the amplifier to the speakers. Use ±10 V to power the op-amp.

TESTING THE RECEIVER

Follow the following steps to configure the AFG as an AM transmitter.

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1. Connect the Channel 2 output to the modulation input for Channel 1 on the back of the AFG.
2. Set Channel 2 to produce a 1 kHz sine wave at 1 volt peak to peak.
3. Turn on the output of Channel 2.
4. Connect a BNC to Banana adapter to Channel 1.
5. Set Channel 1 to produce a 2 V peak-to-peak sine wave at the frequency assigned to you by your teaching assistant.
6. Turn on the output of Channel 1.
7. Connect a banana to alligator lead to the positive side of your BNC to Banana adapter. This will serve as your transmitting antenna while you test your receiver.
8. Press the Modulation button, select Modulation Type AM, and AM Source External.

Keep the Channel 1 amplitude below 2 V to avoid causing interference to other groups. Scan from 700 kHz to 3 MHz with the AFG until you hear a tone from your speakers. You will need to keep the receiver antenna within one foot of your transmitting antenna while you test your receiver.

Answer Questions 11 – 12.

The answers to Questions 11 and 12 give you the tunable band for your radio.

Set Channel 1 of your AFG to the frequency assigned to you by your TA. Adjust your capacitor until the tone in your speakers is loudest. This will tune your receiver to your assigned frequency

BUILDING THE TRANSMITTER

Build the circuit in Figure 6. Use the values you calculated for R3 and R2 in the prelab. Use ±10 V to power the op-amp. Use the +10 V op-amp supply as the input voltage for your microphone. Test your circuit by connecting the output of the op-amp to the speakers at your bench. You should be able to talk into the microphone and hear it amplified through speakers. If you set the speaker volume too high, the speakers will produce a high pitched squeal. This is called feedback. Turn the speaker volume down to eliminate this problem.

Connect the output of your transmitter circuit to the modulation input for Channel 1 on your AFG. Increase the amplitude of Channel 1 to 10 V. Lengthen your transmitting antenna by connecting 3 more banana to alligator leads to the banana to alligator lead already connected to Channel 1. Your transmitting antenna should be about 12 feet long. DO NOT use any cables with BNC connections for your transmitting antenna. These cables are shielded and will not transmit radio waves.

You should now be able to have a radio conversation with the group sharing your frequency. When you transmit, disconnect the power from your receiver and shut off your speakers. When you receive, disconnect power from transmitter and turn off the Channel 1 output on your AFG.

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A.M. RADIO DESIGN LAB

BEFORE YOU BEGIN

PREREQUISITE LABS

- Passive and Active Filters Lab
- Fourier Transforms Lab
- Introduction to Oscilloscope
- Introduction to Arbitrary/Function Generator

EXPECTED KNOWLEDGE

- Laplace transform circuit analysis
- Analog filters
- Op-Amp applications

EQUIPMENT

- TDS3034B Series Digital Phosphor Oscilloscope
- AFG3000 Series Arbitrary/Function Generator
- Programmable Power Supply
- Speaker Switch Box
- Computer Speakers

MATERIALS

- Inductor Bobbin and Wire
- Variable Capacitor (8.5 – 120 pF)
- 2 x 741 Op Amps
- Germanium Diode
- Condenser Microphone
- 20 feet of wire
- Solderless Breadboard

OBJECTIVES

After completing this lab you should know how to:

- Modulate an A.M. signal
- Demodulate an A.M. signal
- Build a simple A.M. receiver

INTRODUCTION

AMPLITUDE MODULATION

Radio stations transmit electromagnetic waves at different frequencies. When you turn the tuning dial on your car radio, you change the frequency that your radio receives. For example, when

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your radio receives an FM station at 107.5 MHz, it is tuned to receive only signals with frequency content that is close to 107.5 MHz.

You can not hear electromagnetic waves and, even if you could, you can not hear frequencies as high as 107.5 MHz. Your can only hear audible frequencies up to about 20 kHz. Radio transmitters "mix" the sound waves into the 107.5 MHz signal and convert it to an electromagnetic wave. This process of mixing two signals at different frequencies is called modulation. Your car radio receives the electromagnetic waves, converts them to electrical signals, separates the audio and radio signals, and sends the audio signal to your speakers.

Radios use one of two methods to "mix" audio frequency sounds into a radio signal. They are frequency modulation (F.M.) and amplitude modulation (A.M.). The scope of this lab is limited to amplitude modulation.

A.M. modulation changes the amplitude of a high frequency, sinusoidal electromagnetic wave by an amount proportional to the amplitude of the sound wave. Figure 1 shows a radio signal with no modulation.

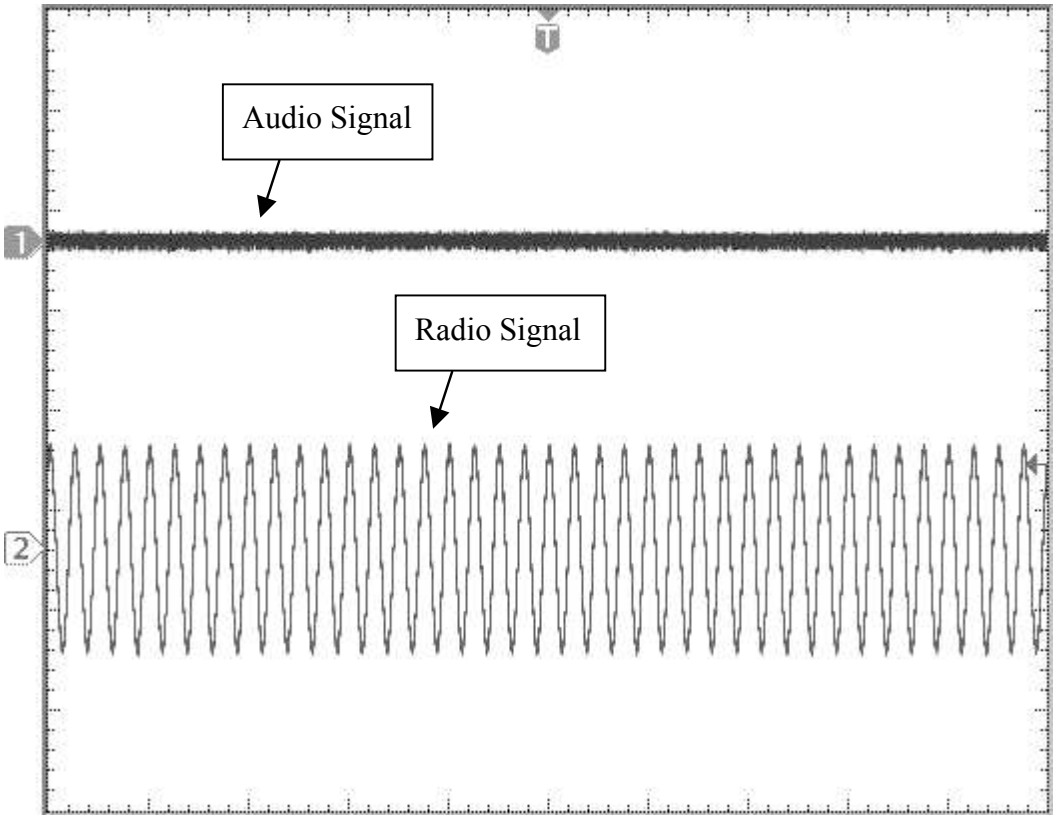


Figure 1: Radio wave with no modulaton

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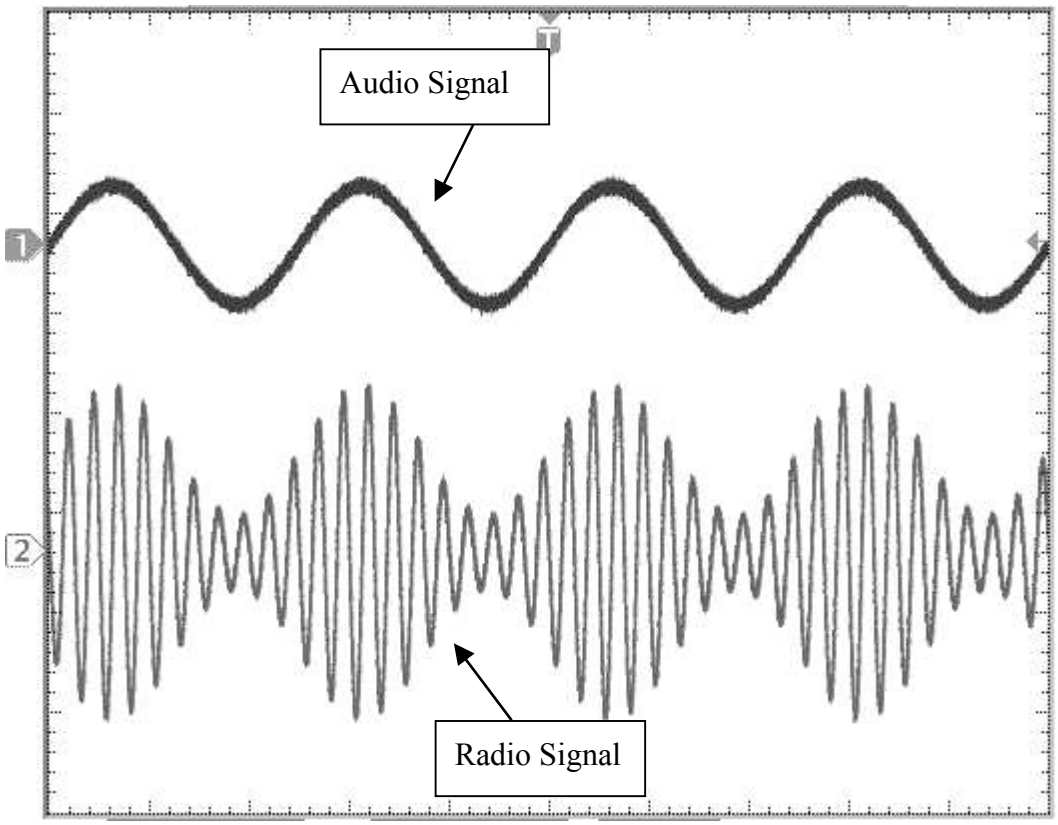


Figure 2: Radio wave with amplitude modulation

Figure 2 shows a radio signal with amplitude modulation. The amplitude of the radio wave follows the amplitude of the sound wave as in Figure 2.

A.M. DEMODULATION

In this lab, we will be using a diode to convert the received signal into an audio signal. This process is called A.M. demodulation.

A diode is a device that only allows current flow in one direction. If we apply an AC signal to one end of a diode, as in Figure 3, we will only see the positive portion of that signal at Vout.

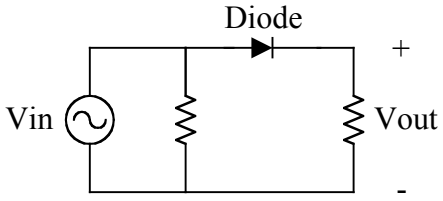


Figure 3: Diode Demonstration Circuit

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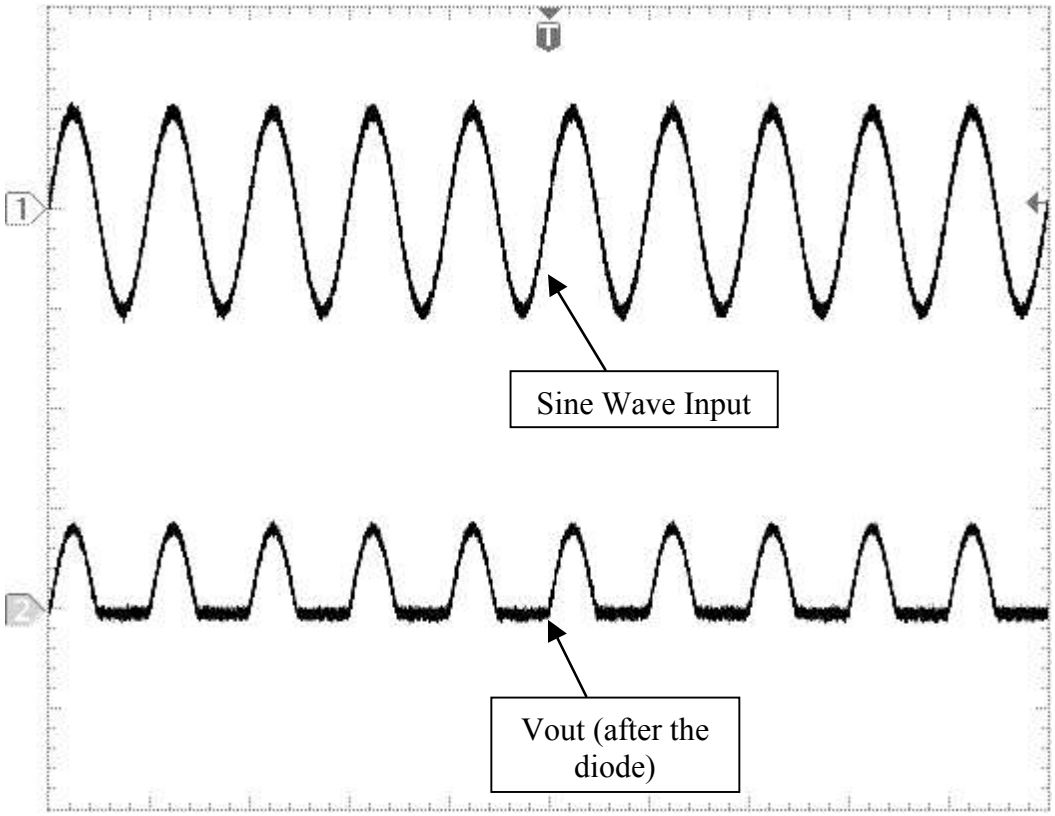


Figure 4: Rectified Sine Wave

As you can see in Figure 4, the diode removes the negative portion of the incoming signal. This is called half wave rectification. The lower waveform in Figure 4 is said to be half wave rectified.

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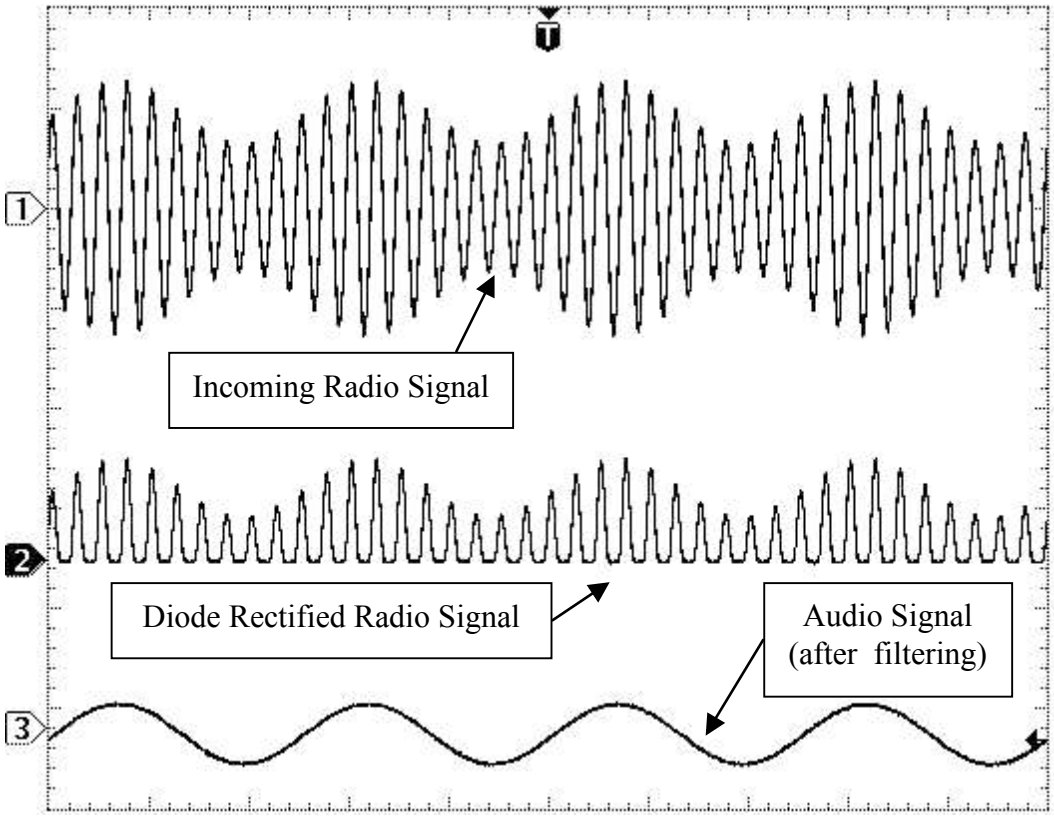


Figure 5: A.M. Radio Wave Rectification

Diode rectification is a simple way to help demodulate an A.M. radio signal. Figure 5 shows how an incoming radio wave is effectively cut in half when it passes through a diode. Since the current can only flow in one direction we will only see positive voltages. The remaining signal is low pass filtered to remove the radio frequency, leaving only the low-frequency audio signal.

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PRELAB

AUDIO SIGNAL GENERATION

To generate our audio signal, we will use a condenser microphone and an op-amp as shown in Figure 6. The condenser microphone needs a small DC current to make it operate correctly. This current is controlled by R3.

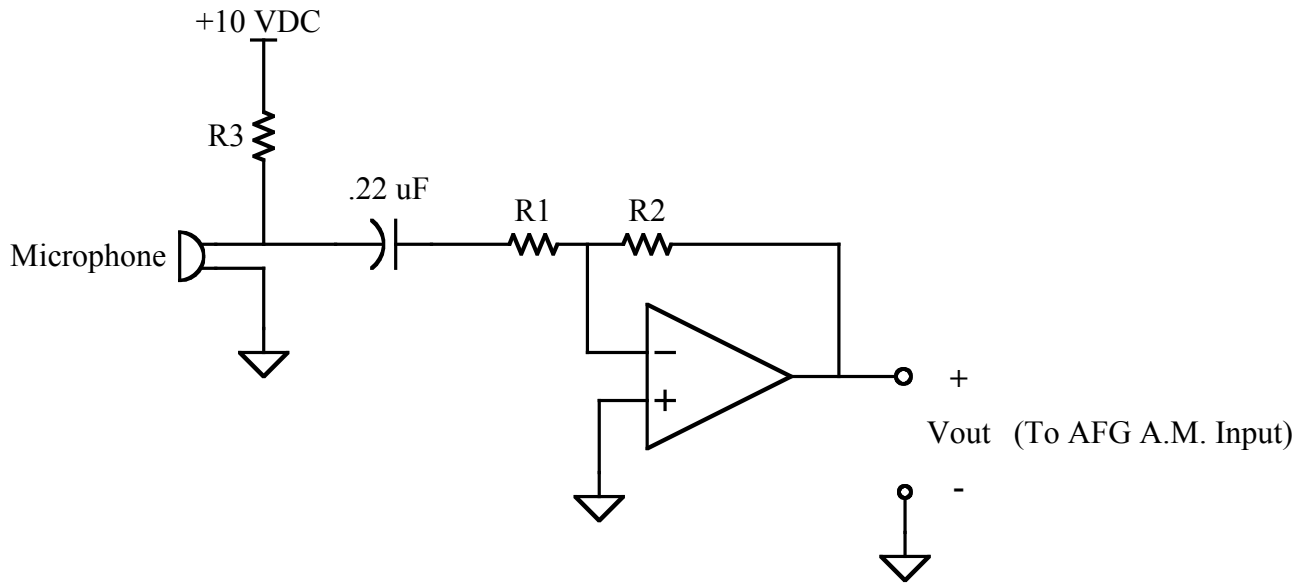


Figure 6: Microphone and Amplifier Circuit

In this configuration, the microphone acts like a sound controlled variable resistor. The sound waves that the microphone picks up control the resistance of the microphone. The changing resistance causes the voltage on the microphone's ungrounded pin to change according to the amplitude of the sound wave on the microphone. This produces an audio frequency AC voltage signal at the microphone's ungrounded pin. The audio AC signal then passes through the large capacitor to block all DC voltages, and is amplified by the inverting amplifier circuit.

Answer Questions 1 – 2.

A.M. RADIO TRANSMISSION

To transmit A.M. signals, we will be using the Arbitrary/Function Generator (AFG). The AFG has a modulation input, and it will amplitude modulate any signal. The only remaining component is the antenna. Radio signals are waves with a specific frequency and wavelength. For an antenna to efficiently broadcast radio waves, it has to be a specific length. According to wave theory, $v = f\lambda$ where v is the velocity of the wave (in our case, 300 M m/s), f is frequency of the wave (in hertz), and λ is the wavelength (in meters). An efficient antenna has a length

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equal to half of a wavelength. For a 1 MHz wave ($\lambda = \frac{v}{f}, \lambda = \frac{300*10^6}{1*10^6}$, λ=300 meters) an efficient antenna would be 150 meters long.

Answer Question 3.

Other slightly less efficient antennas are λ/4 and λ/8 meters long. We are not concerned with making the most efficient antenna, so any antenna length that is 3 meters or longer will work fine. The antenna will be connected to the positive terminal of Channel 1 output of the AFG.

How an Antenna Works

Charged particles emit radiation when they are accelerated and radio waves are one type of radiation. The AC voltage from your AFG forces electrons into and out of the antenna. This AC voltage accelerates the electrons and causes the electrons to emit radio waves that travel perpendicular to the broadcasting antenna. Therefore, it is best to set up you transmitting antenna so it is oriented parallel to your receiving antenna.

IS THIS LEGAL?

In radio talk, a "band" is a group of frequencies that are all used for the same purpose. The A.M. band on your radio starts at 500 kHz and ends at 1800 kHz. Commercial radio stations use these frequencies. Usually, the U.S. Government requires a person or company to obtain a license before they can transmit on any frequency. However, the government does make some exceptions. Anyone can transmit on the A.M. band as long as their transmissions do not cause any harmful interference to existing stations and as long as their transmissions are not too powerful. The small amounts of power that are used in this experiment are within the legal limits.

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A.M. RADIO RECEIVER

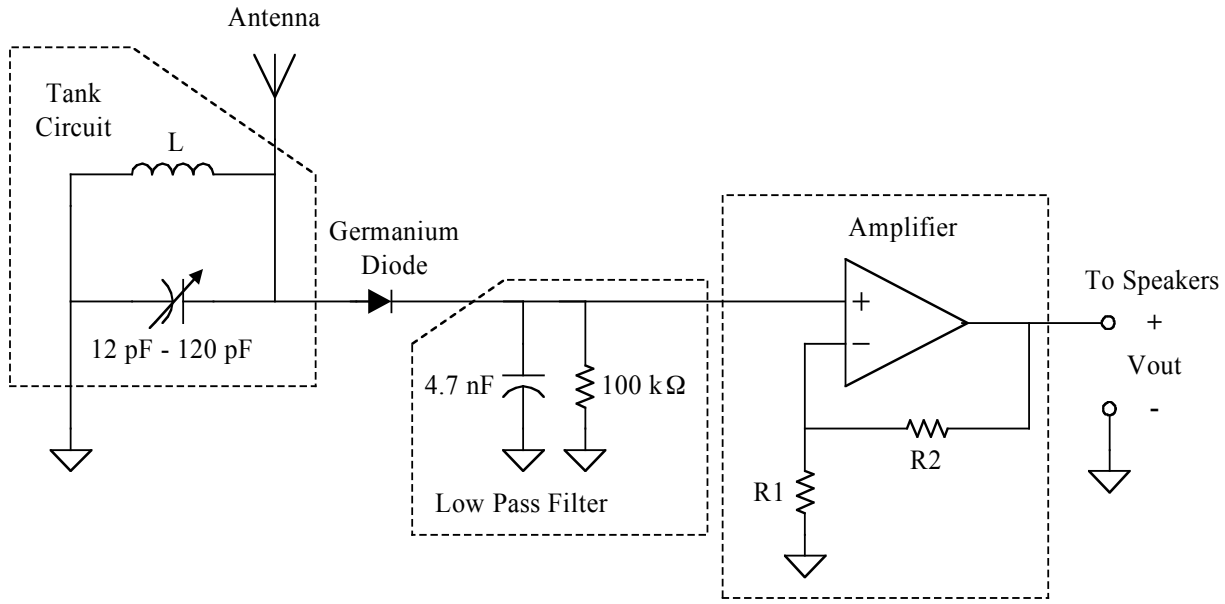


Figure 7: Receiver Circuit

Figure 7 shows the circuit you will build for your radio receiver. This circuit consists of four basic sections: a "tank circuit", a diode, a low pass filter, and a non-inverting amplifier.

The inductor-capacitor parallel combination is commonly called a tank circuit. The tank circuit is a band pass filter with a fairly high Q value. To analyze the tank circuit, we can model the antenna as a sinusoidal current source, as in Figure 8. For this circuit, $\frac{V_o(s)}{I_s(s)} = H(s)$.

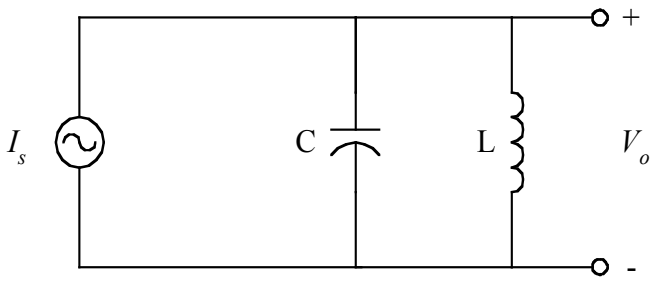


Figure 8: Tank Circuit Analysis

Answer Questions 4 – 5.

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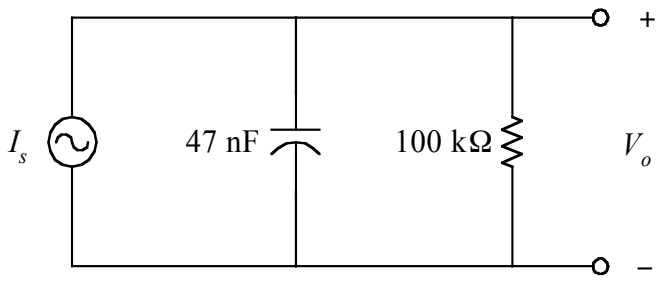


Figure 9: Low Pass Filter Analysis

The capacitor-resistor parallel combination in the receiver circuit is acting as a low pass filter. The current through the diode is acting as the current source in this case.

Answer Question 6.

The op-amp in the receiver circuit is acting as a non-inverting amplifier. We will need a gain greater than 50 to amplify our audio signal enough for us to hear the received signal in the speakers.

Answer Question 7.

BUILDING THE RECIEVER

Your teaching assistant will assign you one of the following frequencies:

1 MHz

1.15 MHz

1.4 MHz

1.8 MHz

2.5 MHz

You will be sharing the frequency with one other group in your lab section.

Answer Question 8.

Unfortunately, factors including parasitic capacitance and resistance change the value you actually need for your inductor. Wrap your inductor bobbin with 150 wraps. **Do not** use the ceramic core to increase the inductance. The ceramic core is intended for use only at low frequencies (<10 kHz). If you use the core, it will greatly decrease the Q value of your tank circuit, making it unsuitable for tuning your radio. You will need to use wire-wrapping wire (AWG 30 or smaller). Connect the inductor and capacitor as in Figure 10.

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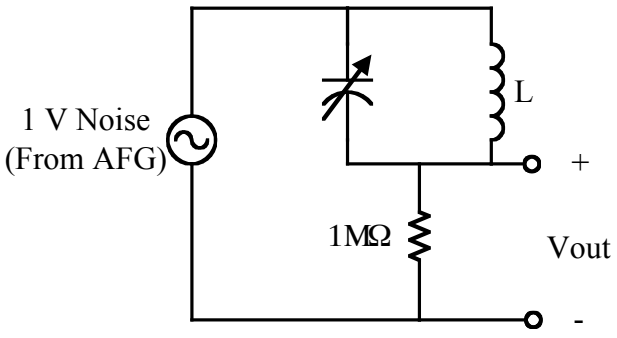


Figure 10: Tank Test Circuit

Change the function on the AFG to Noise and the amplitude to 1 V. At this setting, the AFG will produce white noise that you will feed through your tank circuit. Perform an FFT analysis on the voltage across the 1 MΩ resistor. Set Channel 1 to 100 μs per division and set the FFT to 500 kHz per division. For best results, you will need to have your probe set on 1X and the Channel 1 impedance on the Scope set to 1 MΩ. You should see something like Figure 11 when you have everything set correctly.

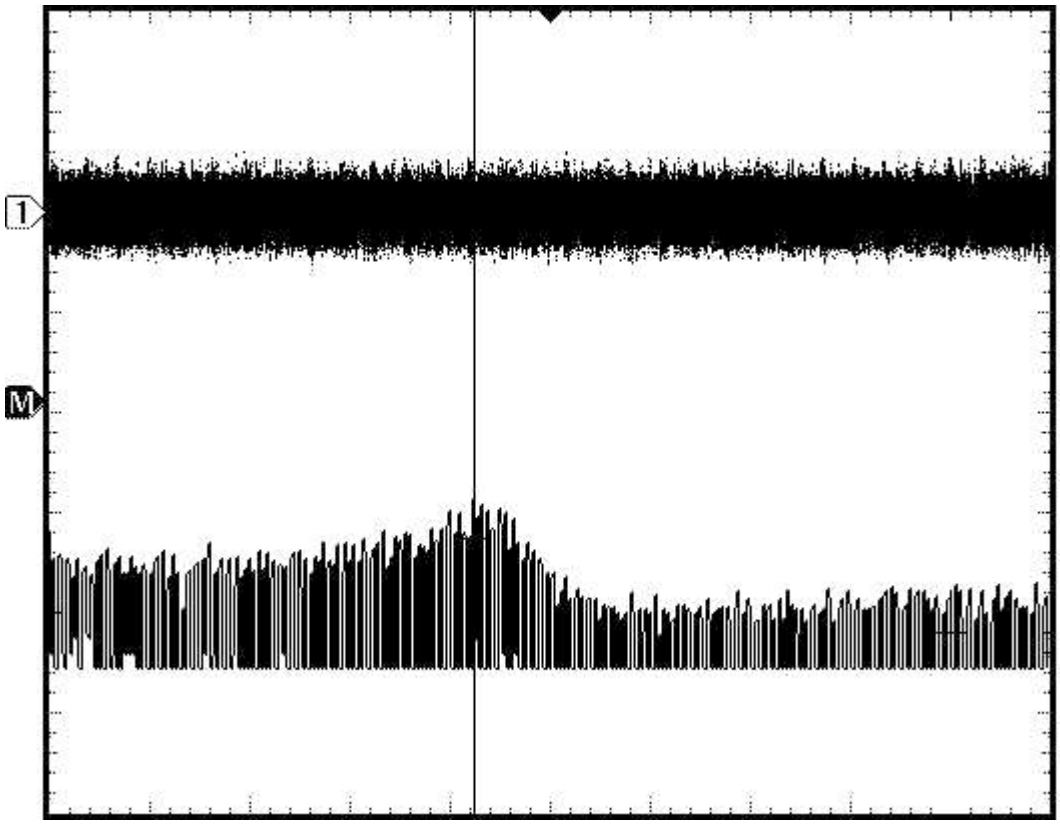


Figure 11: FFT of Noise through Tank Circuit

Figure 11 shows an oscilloscope with Channel 1 activated, and the math plot set to FFT. The bump on the FFT plot corresponds to the resonate frequency of the tank circuit. If you were

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using this circuit to tune in a radio station, the station you would be hearing would be the one transmitting on frequency corresponding to the maximum in your FFT plot. As you adjust your capacitor, you will see the bump on your FFT move left and right. If you do not see this, you are looking at the wrong bump on the FFT. The correct bump will probably be between 100 kHz and 5 MHz.

Answer Questions 9 – 10.

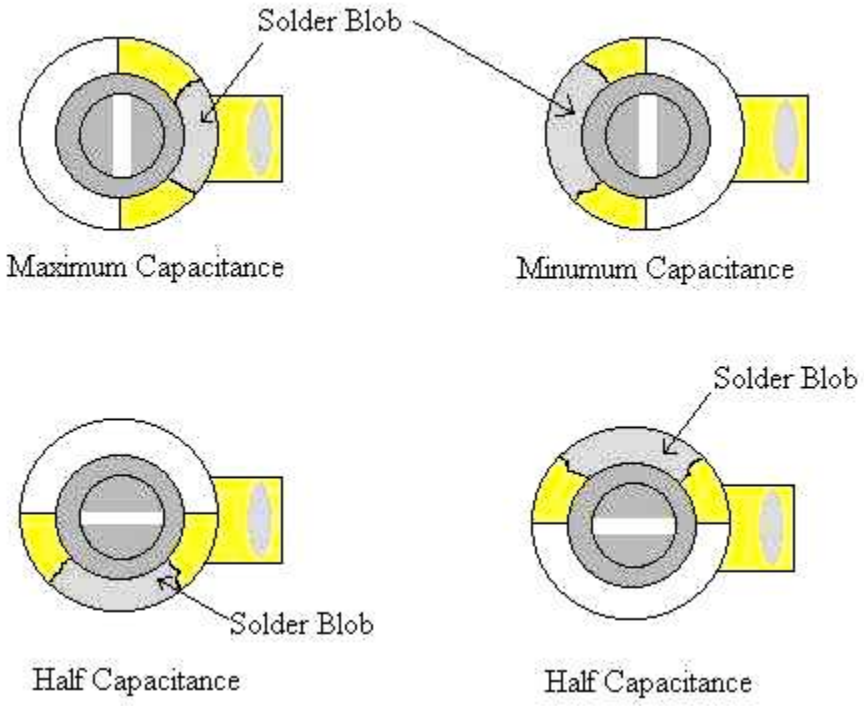


Figure 12: Variable Capacitance Adjustment

Set your capacitor to half capacitance as in Figure 12. You will need to adjust your inductor so that your circuit resonates at the frequency assigned to you when the capacitor is set near its halfway point. If your inductor is too small, the frequency will be too high. You will need to increase the number of wraps on your inductor. If your frequency is too low, you will need to decrease the number of wraps on your inductor.

When you actually combine this tank circuit with the rest of your radio, the tunable frequency range will decrease somewhat due to parasitic capacitance in your solderless breadboard. The frequency assigned to you should still be within your tunable range.

Connect the Receiver Circuit in Figure 7. Use a 10-foot piece of wire for the antenna. Connect the output of the amplifier to the speakers. Use ±10 V to power the op-amp.

TESTING THE RECEIVER

Follow the following steps to configure the AFG as an AM transmitter.

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1. Connect the Channel 2 output to the modulation input for Channel 1 on the back of the AFG.
2. Set Channel 2 to produce a 1 kHz sine wave at 1 volt peak to peak.
3. Turn on the output of Channel 2.
4. Connect a BNC to Banana adapter to Channel 1.
5. Set Channel 1 to produce a 2 V peak-to-peak sine wave at the frequency assigned to you by your teaching assistant.
6. Turn on the output of Channel 1.
7. Connect a banana to alligator lead to the positive side of your BNC to Banana adapter. This will serve as your transmitting antenna while you test your receiver.
8. Press the Modulation button, select Modulation Type AM, and AM Source External.

Keep the Channel 1 amplitude below 2 V to avoid causing interference to other groups. Scan from 700 kHz to 3 MHz with the AFG until you hear a tone from your speakers. You will need to keep the receiver antenna within one foot of your transmitting antenna while you test your receiver.

Answer Questions 11 – 12.

The answers to Questions 11 and 12 give you the tunable band for your radio.

Set Channel 1 of your AFG to the frequency assigned to you by your TA. Adjust your capacitor until the tone in your speakers is loudest. This will tune your receiver to your assigned frequency

BUILDING THE TRANSMITTER

Build the circuit in Figure 6. Use the values you calculated for R3 and R2 in the prelab. Use ±10 V to power the op-amp. Use the +10 V op-amp supply as the input voltage for your microphone. Test your circuit by connecting the output of the op-amp to the speakers at your bench. You should be able to talk into the microphone and hear it amplified through speakers. If you set the speaker volume too high, the speakers will produce a high pitched squeal. This is called feedback. Turn the speaker volume down to eliminate this problem.

Connect the output of your transmitter circuit to the modulation input for Channel 1 on your AFG. Increase the amplitude of Channel 1 to 10 V. Lengthen your transmitting antenna by connecting 3 more banana to alligator leads to the banana to alligator lead already connected to Channel 1. Your transmitting antenna should be about 12 feet long. DO NOT use any cables with BNC connections for your transmitting antenna. These cables are shielded and will not transmit radio waves.

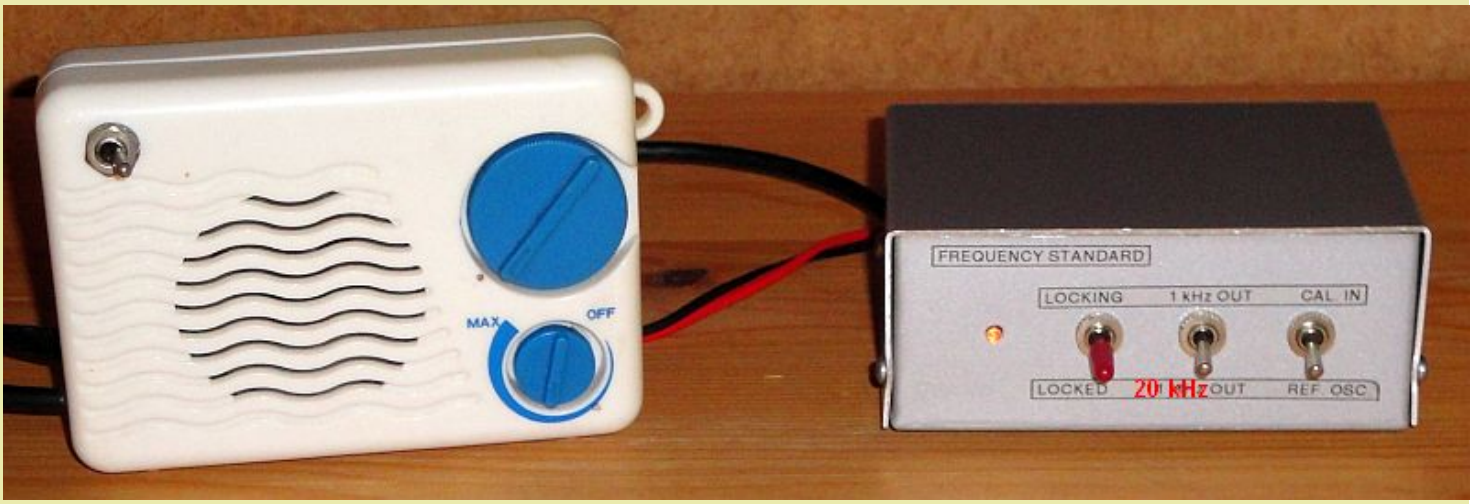
You should now be able to have a radio conversation with the group sharing your frequency. When you transmit, disconnect the power from your receiver and shut off your speakers. When you receive, disconnect power from transmitter and turn off the Channel 1 output on your AFG.

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FREQUENCY STANDARD FOR ALLOUS 162KHZ (MODIFIED DROITWICH STANDARD)

(2012)

KLIK HIER VOOR DE NEDERLANDSE VERSIE



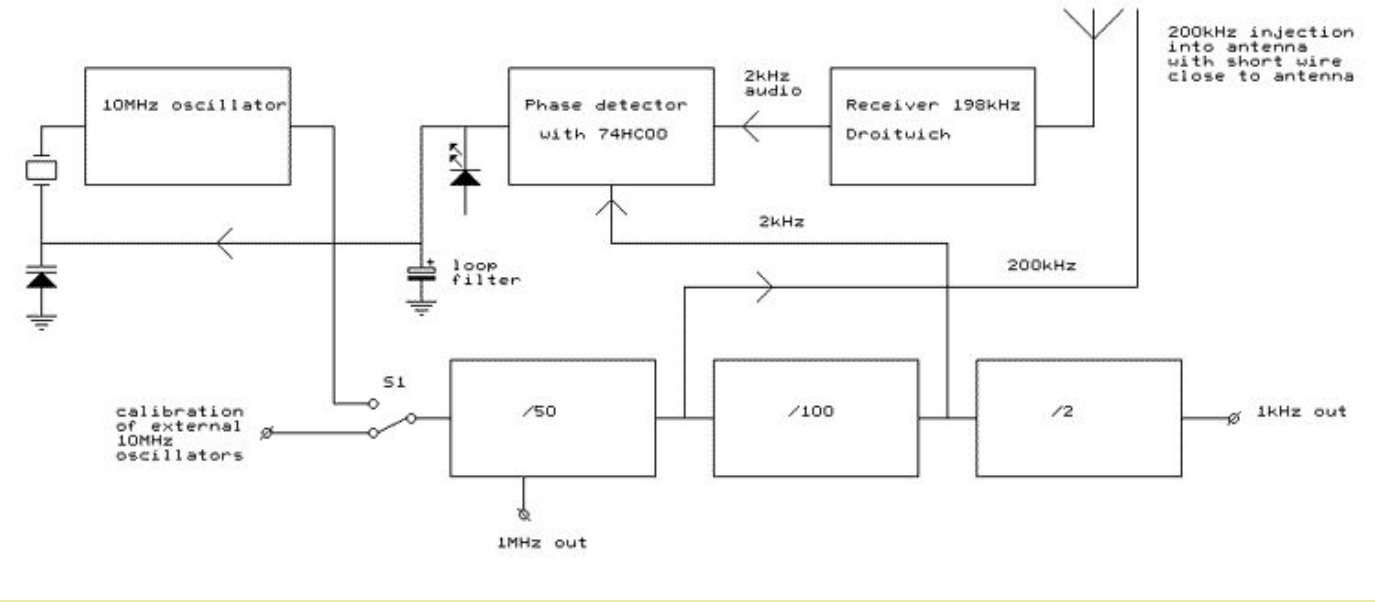
Frequency standard locked at the transmitter Allouis on 162 kHz.
Aand the radio receiver for 162 kHz, a modified medium wave receiver.

Modification of the Droitwich frequency standard for Allouis 162 kHz.
The frequency standard locked at the transmitter Droitwich (BBC on 198 kHz) can be modified very easily for use with the French transmitter Allouis on 162 kHz. We only have to change the wiring between the various divider ic's. And of course, the receiver has to be tuned to 162 kHz instead of 198 kHz. The transmitter Allouis can also be received in Southern Europe. For nothing we can lock our frequency standard at this very accurate signal!
It is not necessary to make a special receiver, a normal longwave broadcast radio can be used that is tuned on 162 kHz.

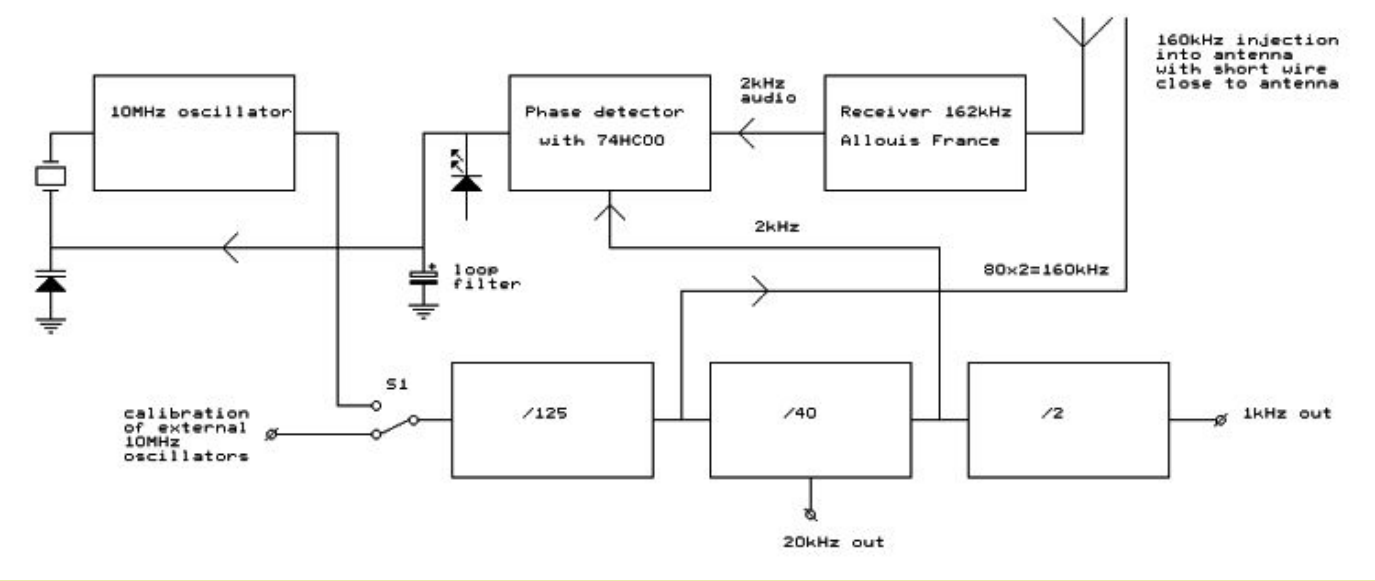


Location of the long wave transmitter Allouis.
It can also be received in Southern Europe.

The differences between the block diagrams
The only difference is the dividers, but it are the same 2 and 5 divider ic's as in the circuit diagram for Droitwich. We only have to change the wiring between the various divider ic's.
The 1 kHz output can be changed into 10 kHz or 1 MHz or other values. I needed the 20 kHz output, it is used for the calibration of the QRSS beacon receiver.



Block diagram of the original frequency standard for Droitwich.



Block diagram of the modified frequency standard for Allouis.
Only the dividers are different, but it are the same ic's.

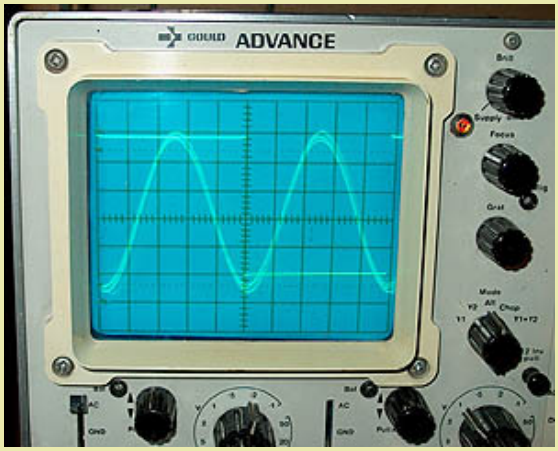
How does it work?
The signal on 162 kHz is received with an ordinary broadcast receiver.
The 10 MHz crystal oscillator is divided by 125 and by 5000. From the signal after the 125 divider (80 kHz), the 2nd harmonic is used. Now we have a 160 kHz and a 2 kHz signal. The 160 kHz signal is injected into the ferrite antenna of the broadcast radio. Together with the 160 kHz signal, the 162 kHz signal of Allouis will cause an interference tone of 2 kHz in the loudspeaker. This audio tone of 2 kHz is compared in a phase detector to the 2 kHz signal from the divider. When both 2 kHz signals are not exactly the same, the frequency of the 10 MHz oscillator is controlled.
The 2 kHz audio signal is filtered to suppress speech and music of the broadcast transmitter.
I did need an accurate 20 kHz signal for the calibration of my QRSS beacon reception receiver on 10140 kHz and an accurate 1 kHz signal. But you can change the 1 kHz signal to 10 kHz, 200 kHz or 1 MHz and even 5 MHz. And also 10 MHz if you do use the remaining NAND as a buffer. But of course you can choose your own desired frequencies from the outputs of the various dividers.



Longe wave broadcast receivers that can be used
for the reception of Allouis 162 kHz and Droitwich 198 kHz.

Calibration of external 10 MHz oscillators

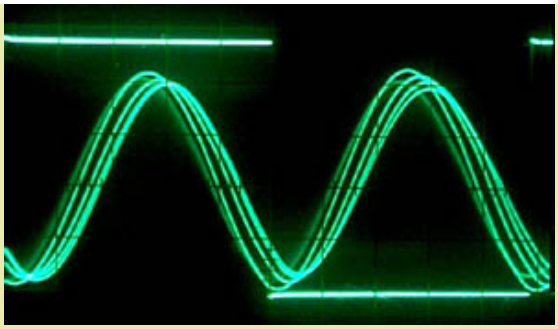
To calibrate external 10 MHz oscillators, the switch S1 is set to the other position and the internal 10 MHz oscillator is replaced by the external 10 MHz signal. This oscillator is not controlled of course, we have to adjust it ourselfs. On the screen of an oscilloscope the filtered 2 kHz audio signal from the broadcast receiver is displayed. The oscilloscope is triggered by the 1 kHz signal from the dividers. The only thing we have to do now is to adjust the 10 MHz oscillator so that the 2 kHz sine of the audio signal does not move to the left or to the right on the screen. When the sine moves one period in 1 minute, then the error of the 10 MHz oscillator is approximately 1 Hz.



Calibration with an oscilloscope. The audio signal on the screen does
not move to the left or right when the frequency is exactly 10 MHz.
Triggering is done by the 1 kHz signal on channel 2.

Phase modulation of data signals

Unfortunately, we can not use the 162 kHz signal without any problem. It has phase modulation for the transmission of data. You can see that on the screen of the oscilloscope here below. The sine has jitter. This phase modulation has to be suppressed in the loopfilter of the frequency control, otherwise it will disturb the accuracy of the 10 MHz signal of the frequency standard. This can be done by making the loopfilter very slow. By doing so, the control loop will become also less sensitive for radio interference. The loopfilter in the circuit has two positions: a fast one to lock the oscillator and a slow one for when the crystal oscillator is locked.



Phase modulated data signals have to be filtered out in the loopfilter by making it very slow!

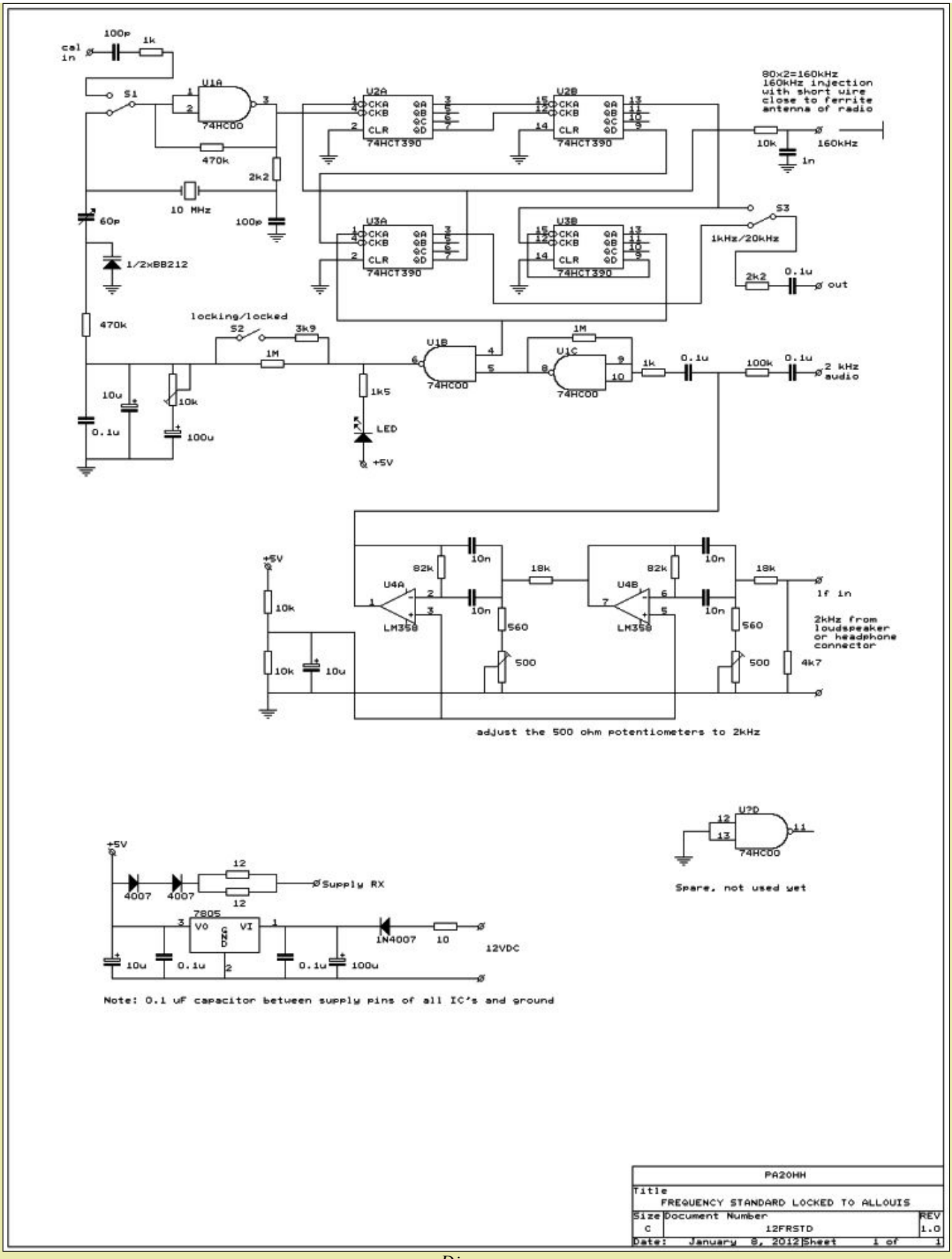
The diagram

Right above, you can find the 10 MHz crystal oscillator. With S1 you can select the internal oscillator that is controlled or for an external 10 MHz oscillator that has to be calibrated (adjusted). The internal 10 MHz oscillator is controlled by a varicap BB212 of which only one half is used. Both 74HCT390 are the frequency dividers, it are /2 and /5 dividers.
The 160 kHz signal is injected into the receiver with a short piece of wire that is mounted close to the ferrite antenna. So not a small loop around or close to the ferrite antenna, but capacitive coupling with a piece of wire, that does work much better. Play a little with the length and place of the wire and the value of the 10k resistor. I had to change the 10 ohm into 2200 ohm, as more signal was required than for Droitwich. The 2nd harmonic of 80 kHz does have a lower level than the signal of 200 kHz in the Droitwich diagram.

Other standard frequencies

It is very simple to change the 1 kHz standard frequency to other values. For that, we need th connect pin 1 of U3a with another divider as given in the diagram:

Wanted standard frequency	Connect pin of U3a with
1 kHz	pin 13 of U3b
10 kHz	pin 13 of U2b
200 kHz	pin 9 of U2b
1 MHz	pin 7 of U2a



Diagram

The wiring has been changed an the 10k ohm resistor changed to 2200 ohm.

big diagram

The 2 kHz audio signal of the receiver (headphones output) is connected to "lf in" and filtered in 2 active filters with a LM358. What remains is a good useable 2 kHz signal without interference of music and speech. Both filters should have a Q factor of 10 and a gain of 2x2=4x. With the 500 ohm potentiometers, they are exactly adjusted to 2 kHz. The filtered audio signal can be monitored with an oscilloscope by connecting it to "2 kHz audio".

The NAND U1C does make a square wave of the 2 kHz audio signal. U1B is the phase detector. The average value of the output voltage of this phase detector varies between 2.5 V and 5.0 V, perfect to control the varicap. Phase modulation and the 2 kHz square wave are filtered out in the loopfilter.

The loopfilter has two capacitors, one of 10 uF and one of 100 uF. The 10 uF capacitor removes the 2 kHz signal. With S2, the time constant of the filter can be selected for "locking" or "locked" or fast or slow. The loopfilter is too slow with the 1M ohm resistor to get the oscillator locked. When the oscillator is locked, the switch is set to the position "locked" and the 10 MHz oscillator is controlled very slowly. Phase modulation, the 2 kHz square wave and interference do have hardly any influence anymore on the stability in this position of the switch.
The stability of the control loop can be adjusted with the 10k potentiometer in series with the 100 uF capacitor. At 0 ohm, it will take much time before the circuit is stabilized, the frequency goes up and down very long. Also after interferences, stabilization takes a long time. With the potentiometer adjusted to 5k ohm, stabilization goes much quicker.
With the led you can check if the circuit is locked. If not, then the led goes slowly on and off with the frequency difference between both 2 kHz signals.
One NAND is not used, you can use that for example as a buffer after the crystal oscillator when you do need a 10 MHz signal.

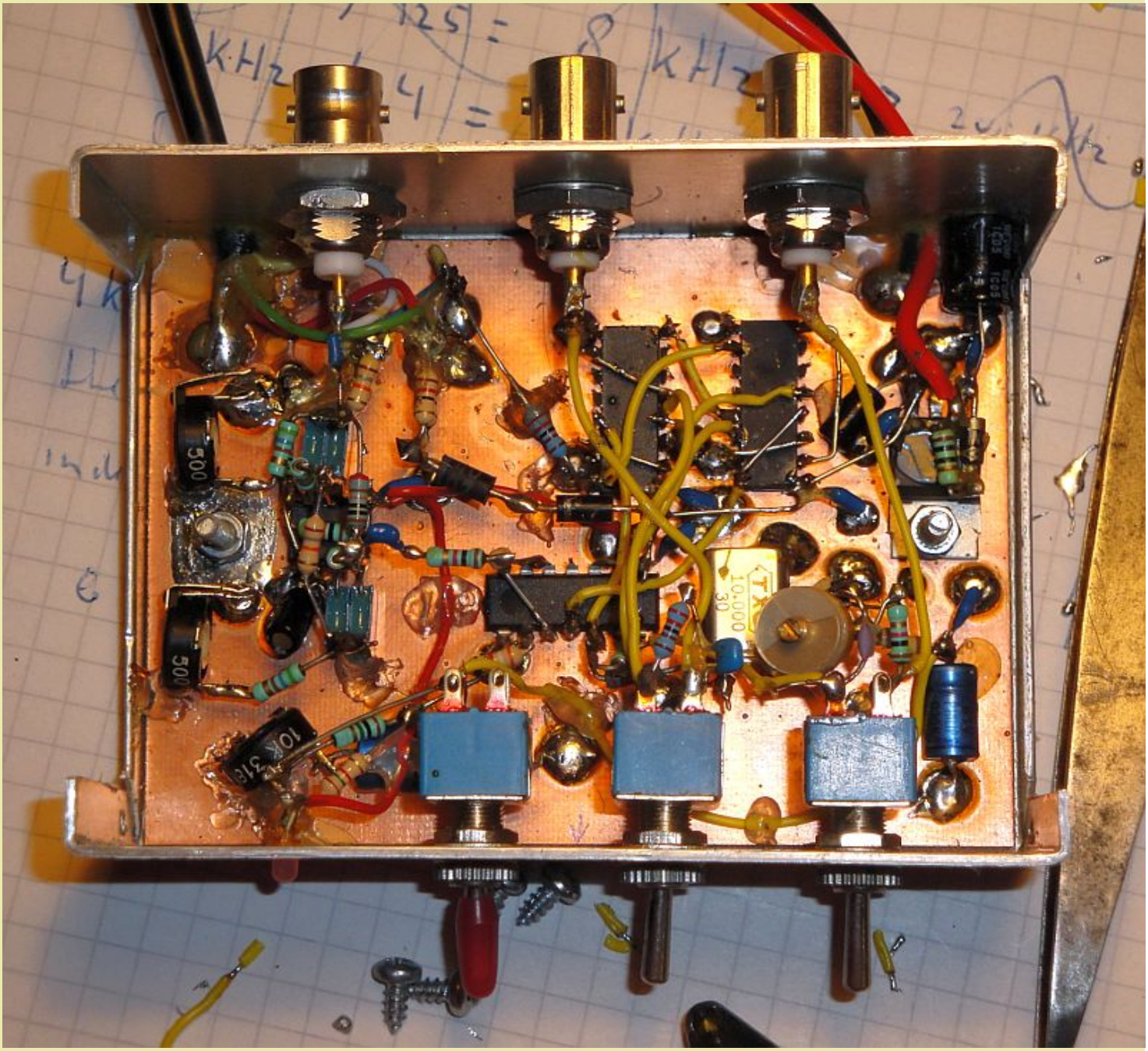


Instead of a long wave broadcast receiver, a modified medium wave receiver is used for the reception of Allouis 162 kHz.

Modified medium wave receiver
The frequency standard worked perfect with the portable radio. But on a flea market, I did buy a small medium wave radio for only 0.50 Euro. It was modified for the reception of Allouis on 162 kHz by placing capacitors in parallel with the two sections of the tuning capacitor. To the section for the ferrite antenna, it was 1650 pF (1500 pF + 150 pF) and the oscillator section 150 pF. The 3 volt supply is taken from the 5 volt stabilizer of the frequency standard via two diodes to lower the voltage. The radio is permanently connected with the frequency standard by means of a 4 wire screened cable with a length of 1 meter. Supply, audio and the 160 kHz injection signal go through this cable. The loudspeaker can be switched on or off with a switch.

Results

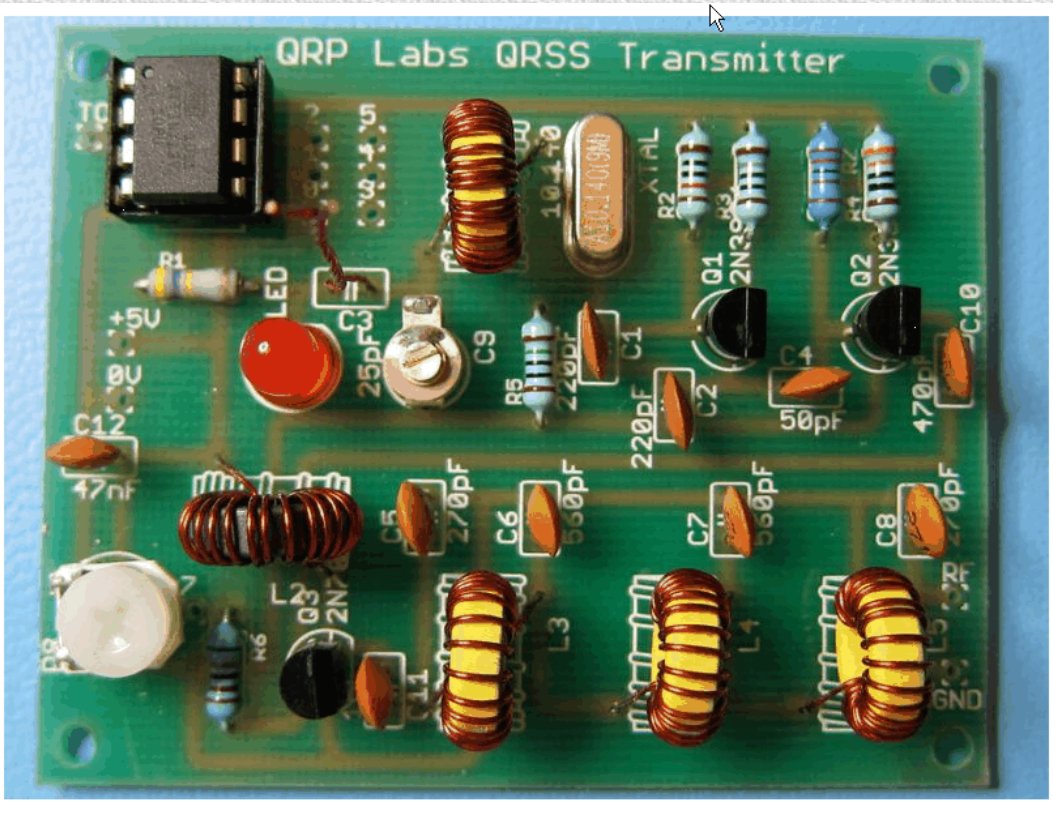
A good impression of the accuracy can be obtained by comparing the 2 kHz audio signal with the 2 kHz (or 1 kHz) signal from the dividers with an oscilloscope. After that the control loop has stabilized, the variations during a few seconds are approximately 1/50 period. Or, the 2 kHz sine moves 1/50 period to the left or to the right during a few seconds. This is difficult to measure because of the phase modulation. Variations are caused by instability of the 10 MHz oscillator, interference (fading) in the reception and modulation of the transmitter with speech and music. So the frequency error of the 10 MHz oscillator is less than 1 Hz. For us, radio amateurs, more than sufficient!



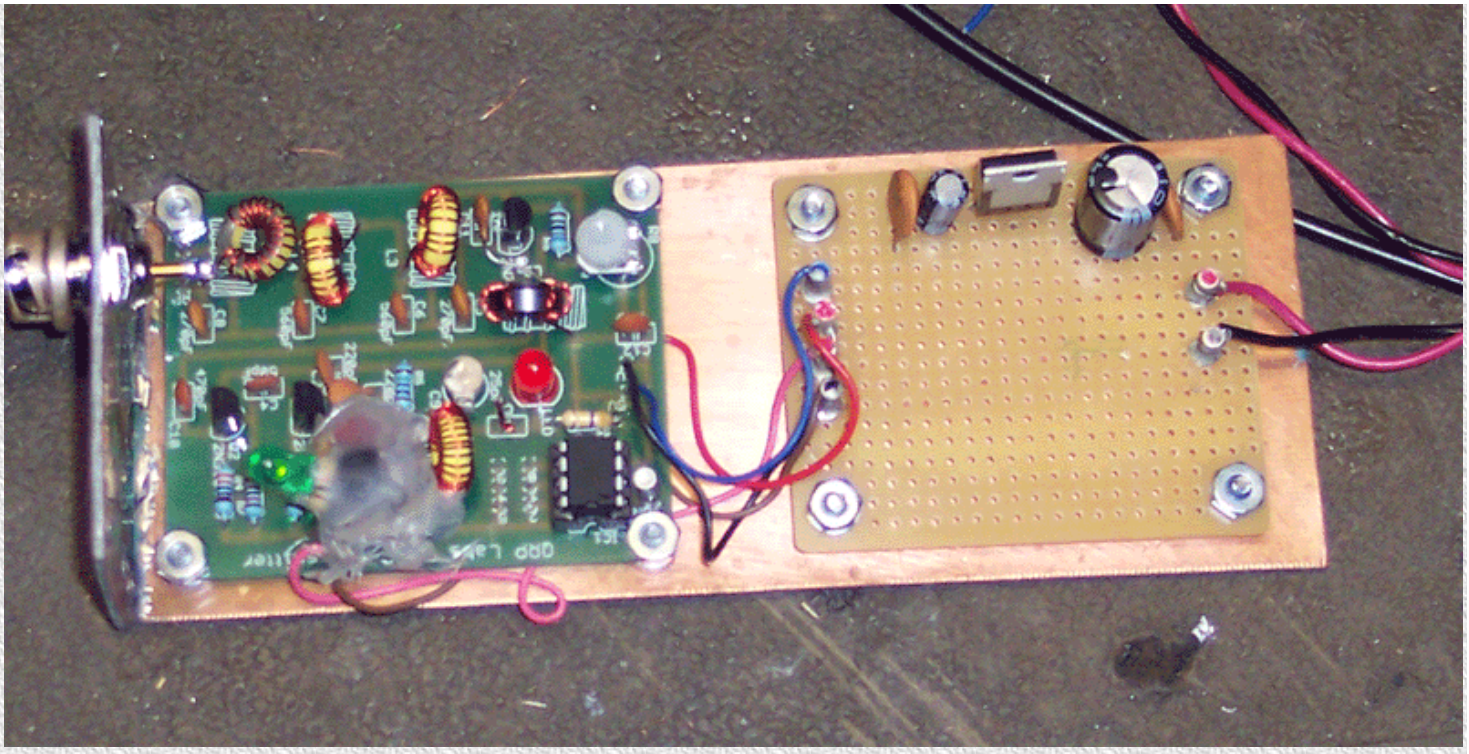
Inside view

BACK TO INDEX PA2OHH

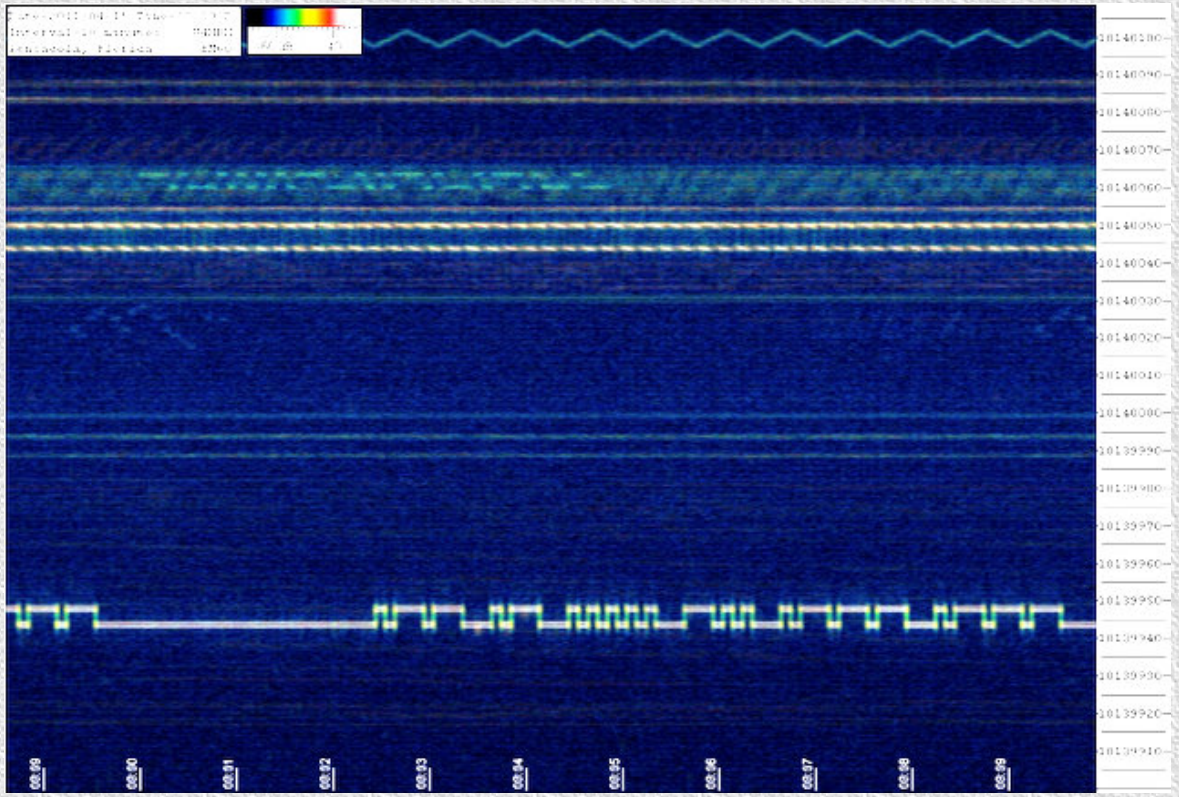
QRP LABS MEPT TRANSMITTERS



Early in 2010 Steve G0XAR and Hans G0UPL produced a inexpensive QRSS Transmitter kit that allowed many hams worldwide to put a signal on the air. There were actually 3 different transmitters, One for 80,40, and 30 Meters. You had to tell them your call sign when ordering and it was preprogrammed into the keyer microprocessor. They all work very well and are very popular. I hear a new version is about to be released. Like most things in the kit world, there are many modifications devised by other cleaver Amateurs. I have two of these transmitters presently on the air and am almost ready to build an 80M model by gathering up a few more parts. (I had the PC board only for the 80M transmitter). They came with a instruction sheet and could easily be built in an evening. The more popular modifications are W4HBK's crystal heater, ZL2UJG 12VDC power modification for the final Amplifier, and N0QHB's Keyer modification that sends the callsign keying out in precise 10 minute intervals. (this allows it to be "stacked" allowing signal detection at very low transmitter power outputs) The new transmitters signals started popping up on grabbers all over the world and it seems that every week there is a new Station to QSL that you have received their signal. I am not sure how many transmitters Hans and Steve have sold but from the increased traffic on the grabbers I believe, It was a bunch.



The above transmitter is the way I packaged my 30M QRP Labs Kit. The hobby board to the right is how I solved the 12VDC and 5VDC power supply by making the 5VDC supply using a 7805 voltage regulator off the 12VDC supply. Mine also has the W4HBK crystal heater modification hidden under the blob of hot melt glue with the green indicator LED peeking out the top of the blob. I did install the ZL2UJG 12Volt final amplifier modification and the Keyer Chip is the N0QBH 12F629 PIC keyer chip. The transmitter puts out about 350mW maximum power before the 2N7000 FET final starts to get warm to the touch. With a heat sink on it, you can probably get more power, but I didn't want to push it.



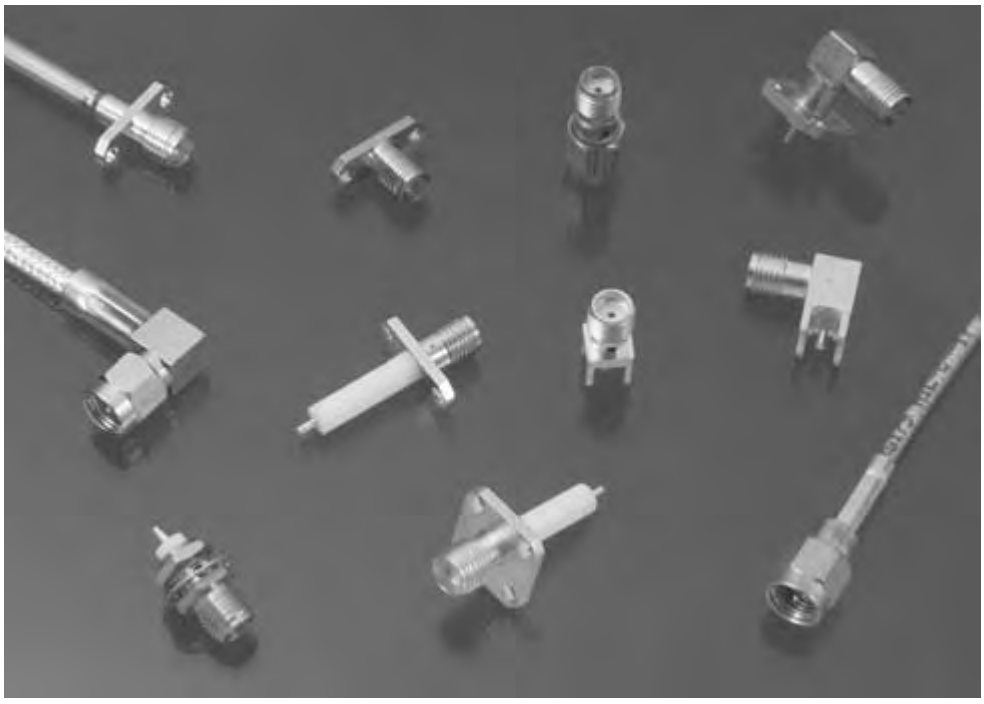
This Grabber stacked image says it all. It is a stack of a 40mW signal from Las Cruces, NM to W4HBK's Grabber in Pensacola, FL. It was 4 hours of stacking the 10 minute grabber images. My signal is rock solid in in frequency and the repeating of the WA5DJJ call sign is spot on the 10 minute interval. I built this transmitter to perform some upcoming very low transmitted power tests using FSKCW modulation. I had to make the signal "stackable" if I was going to achieve the very low signal transmitting tests and have them received.

back to MEPT Transmitter page

SMA Connectors

Product Facts

- **Performance to 12.4 GHz and beyond**
- **Available in various base metal options, including stainless steel, brass and zinc diecast**
- **Uses industry standard crimp tools and processes**
- **Available with corrosion resistant, non-magnetic White Bronze plating**
- **Meets all performance requirements for MIL-C-39012.**



Tyco Electronics offers a complete line of SMA connectors designed for performance to 18 GHz to satisfy the growing demand for SMA connectors in the wireless communications industry. The SMA product line offers stainless steel bodies, as well as non-ferrous metals. Various plating options are available, including Gold and White Bronze. The SMA interface is fully compatible with Mil-C-39012.

While still offering various options on military (QPL) approved connectors, Tyco Electronics has developed a complete offering tailored to the commercial Communications industry. This includes 3 piece flexible cable products for popular RG 316, 142 and RD 316 cable utilizing industry standard HEX crimps.

The SMA series meets the performance, quality and application requirements of the commercial marketplace. This includes White Bronze plating, a unique finish developed by Tyco Electronics to address the performance needs of the telecommunications market. This plating is highly resistant to wear, and contains no ferrous metals, thus displaying excellent intermodulation characteristics.

To satisfy the broad range of commercial applications, SMA connectors are available in a broad range of standard configurations including; straight and right-angle cable applied plugs, bulkhead cable jacks, two and four hole flange mount panel jacks, straight and right-angle pcb mount jacks and various between and in series adapters. Numerous packaging and testing options are also available to meet specific system criteria as well.

Additionally, standard military approved (QPL) interfaces are offered as well. Including connectors for semi-rigid cable and micro strip applications.

The 3 Piece SMA offering is designed especially for applications in cellular infrastructure where InterModulation Products (IMP) must be minimized. By limiting non-linearities within the connectors, IMP is reduced and increased channel capacity can be offered.

Between Series Adapters

For SMA Between Series Adapters, see pages 251-260.

Catalog 1307191
Revised 3-07

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Japan: 81-44-844-8013
UK: 44-8706-080-208

SMA Connectors (Continued)

Specifications

	MIL-C-39012 Applicable Paragraph	
General		
Material	3.3	Steel corrosion resistant per ASTM-A-582 and ASTM-A-484, Type 303. Beryllium copper per ASTM-B-196. PTFE Fluorocarbon per ASTM-D-1710.
Finish	3.3.1	Center contacts shall be gold plated to a min. thickness of .00127 [.00005] in accordance with MIL-G-45204, ASTM-B-488. All other metal parts shall be finished as to provide a connector which meets the corrosion requirements.
Design	3.4	The design shall be such that the outline shown in this catalog and the interface dimensions of MIL-STD-348A are met.
Electrical		
Insulation Resistance	3.11	The insulation resistance shall not be less than 10,000 megohms.
Corona Level	3.22	Refer to applicable military slash sheet, product drawing or spec.
Dielectric Withstanding Voltage	3.17	Refer to applicable military slash sheet, product drawing or spec.
RF High Potential	3.23	Refer to applicable military slash sheet, product drawing or spec.
Contact Resistance	3.16	Refer to applicable military slash sheet, product drawing or spec.
VSWR	3.14	Refer to applicable military slash sheet, product drawing or spec. Frequency range dependent on cable used.
RF Leakage	3.26	Refer to applicable military slash sheet, product drawing or spec.
Insertion Loss	3.27	Refer to applicable military slash sheet, product drawing or spec. Frequency range dependent on cable used.
Mechanical		
Force to Engage	3.5.1	The torque required to engage and disengage shall not exceed 2 in.-lbs. The longitudinal force is not applicable.
Coupling Nut Retention	3.25	60 lbs. min. Applicable for plug connectors only.
Coupling Proof Torque	3.6	15 in.-lbs. min. Applicable for plug connectors only.
Cable Retention	3.24	Refer to applicable military slash sheet or consult factory.
Mating Characteristics	3.7	Applicable to jack connectors only. Reference MIL-STD-348A for dimensions; oversize test pin .953 [.0375] min. dia., .76 - 1.14 [.030-.045] deep, insertion force 3 lbs. max. with .940 [.0370] min. dia. pin, withdrawal force 1 oz. min. with .902 [.0355] max. dia. pin.
Connector Durability	3.15	The connector to be tested and its mating connector shall be subjected to 500 insertion and withdrawal cycles at 12 cycles per minute max. The connector shall show no evidence of mechanical failure and shall meet the mating characteristic requirements.
Recommended Mating Torque	—	7 to 10 in.-lbs.
Environmental		
Vibration	3.18	Specification MIL-STD-202, method 204, test condition D
Shock	3.19	Specification MIL-STD-202, method 213, test condition I
Thermal Shock	3.20	Refer to applicable military slash sheet or consult factory.
Corrosion (Salt Spray)	3.13	Specification MIL-STD-202, method 101, test condition B.
Moisture Resistance	3.21	Specification MIL-STD-202, method 106. No measurements at high humidity. Insulation resistance shall be at least 200 megohms within 5 minutes of removal from humidity.

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SMA Connectors (Continued)

Electrical

Connector Type	Cable	Frequency Max. (GHz)	VSWR x (fGHz)	Contact Resistance (milliohms max.)		Insulation Resistance (megohms min.)	Dielectric Withstanding Voltage (Volts RMS)	Corona Extinction Voltage at 70,000 Ft. (V RMS min.)	RF Transmission Loss	RF High Potential at 5 MHz (V RMS)	RF Leakage (dB min.)
				Center Contact	Outer Contact						
Straight Cable Plug without Contact	RG 402 (3.58 [.141])	Note 1	1.02 + .005	N/A	2.0	10,000	N/A	250	N/A	670	-(90-fGHz)
Straight Cable Plugs & Jacks Solder Attachment	RG 405 (2.16 [.085])	18.0	1.05 + .005	2.0	2.0	10,000	1000	250	.03 √f(GHz)	670	-(90-fGHz)
	RG 402 (3.58 [.141])	18.0	1.05 + .005	2.0	2.0	10,000	1500	375	.03 √f(GHz)	1000	-(90-fGHz)
	3.58 [.141] Microporous	18.0	1.05 + .005	2.0	2.0	10,000	1500	375	.03 √f(GHz)	1000	-(90-fGHz)
	RG 401 (6.35 [.250])	18.0	1.07 + .007	2.0	2.0	10,000	1500	375	.03 √f(GHz)	1000	-(90-fGHz)
	RG 174, 188, 316	Note 1	1.15 + .01	2.0	2.0	10,000	750	190	.06 √f(GHz)	500	-(60-fGHz)
	RG 55, 58, 141, 142, 223, 303, 400	Note 1	1.10 + .005	2.0	2.0	10,000	1000	250	.06 √f(GHz)	670	-(60-fGHz)
Straight Cable Plugs & Jacks Solder Clamp Attachment	RG 405 (2.16 [.085])	12.4	1.10 + .015	2.0	2.0	10,000	1000	250	.03 √f(GHz)	670	-(90-fGHz)
	RG 402 (3.58 [.141])	12.4	1.07 + .01	2.0	2.0	10,000	1500	375	.03 √f(GHz)	1000	-(90-fGHz)
Straight Cable Plugs & Jacks Clamp Attachment	RG 55, 58, 141, 142 223, 400	Note 1	1.10 + .005	2.0	2.0	10,000	1000	250	.06 √f(GHz)	670	-(60-fGHz)
	RG 174, 188, 316	Note 1	1.15 + .01	2.0	2.0	10,000	750	190	.06 √f(GHz)	500	-(60-fGHz)
	RG 180, 195	Note 1	—	2.0	2.0	10,000	750	190	—	500	-(60-fGHz)
Straight Cable Plugs & Jacks Crimp Attachment	RG 55, 142, 223, 400	Note 1	1.10 + .005	2.0	2.0	10,000	1000	250	.06 √f(GHz)	670	-(60-fGHz)
	RG 58, 141, 303	Note 1	1.10 + .005	2.0	2.0	10,000	1000	250	.06 √f(GHz)	670	-(60-fGHz)
	RG 174, 188, 316	Note 1	1.15 + .01	2.0	2.0	10,000	750	190	.06 √f(GHz)	500	-(60-fGHz)
	RG 180, 195	Note 1	—	2.0	2.0	10,000	750	190	—	500	-(60-fGHz)
	RG 178, 196	Note 1	1.2 + .02	2.0	2.0	10,000	500	125	.06 √f(GHz)	335	-(60-fGHz)
Straight Cable Plugs & Jacks Compression Clamp Attachment	RG 401 (6.35 [.250])	18.0	1.07 + .01	2.0	2.0	10,000	1500	375	.05 √f(GHz)	1000	-70 dB min.
	6.35 [.250] Microporous	18.0	1.07 + .01	2.0	2.0	10,000	1500	375	.05 √f(GHz)	1000	-70 dB min.
	6.35 [.250] 3 Spline	18.0	1.07 + .01	2.0	2.0	10,000	1500	375	.05 √f(GHz)	1000	-70 dB min.
	6.35 [.250] 5 Spline	18.0	1.07 + .01	2.0	2.0	10,000	1500	375	.05 √f(GHz)	1000	-70 dB min.
Right-Angle Cable Plugs Solder Attachment	RG 405 (2.16 [.085])	12.4	1.18 + .015	2.0	2.0	10,000	1000	250	.04 √f(GHz)	670	-(90-fGHz)
	RG 405 (2.16 [.085])	18.0	1.18 + .015	2.0	2.0	10,000	1000	250	.04 √f(GHz)	670	-(90-fGHz)
	RG 402 (3.58 [.141])	12.4	1.15 + .015	2.0	2.0	10,000	1500	325	.04 √f(GHz)	1000	-(90-fGHz)
	RG 402 (3.58 [.141])	18.0	1.10 + .010	2.0	2.0	10,000	1500	250	.05 √f(GHz)	1000	-(90-fGHz)
	RG 55, 58, 141, 142, 223, 303, 400	Note 1	1.15 + .01	2.0	2.0	10,000	1000	250	.07 √f(GHz)	670	-(60-fGHz)
	RG 174, 188, 316	Note 1	1.15 + .02	2.0	2.0	10,000	750	190	.07 √f(GHz)	500	-(60-fGHz)
Right-Angle Cable Plugs Crimp Attachment	RG 55, 142, 223, 400	Note 1	1.15 + .02	2.0	2.0	10,000	1000	250	.07 √f(GHz)	670	-(60-fGHz)
	RG 58, 141, 303	Note 1	1.15 + .02	2.0	2.0	10,000	1000	250	.07 √f(GHz)	670	-(60-fGHz)
	RG 174, 188, 316	Note 1	1.18 + .02	2.0	2.0	10,000	750	190	.07 √f(GHz)	500	-(60-fGHz)
	RG 180, 195	Note 1	—	2.0	2.0	10,000	750	190	—	500	-(60-fGHz)
	RG 178, 196	Note 1	1.25 + .025	2.0	2.0	10,000	500	125	.07 √f(GHz)	335	-(60-fGHz)
Right-Angle Cable Plugs Clamp Attachment	RG 55, 58, 141, 142, 223, 303	Note 1	1.10 + .005	2.0	2.0	10,000	1000	250	.08 √f(GHz)	670	-(60-fGHz)
	RG 174, 188, 316	Note 1	1.15 + .01	2.0	2.0	10,000	750	190	.08 √f(GHz)	500	-(60-fGHz)
	RG 180, 195	Note 1	—	2.0	2.0	10,000	750	190	—	500	-(60-fGHz)
Flange Mount Plugs & Jacks Panel or Bulkhead Mount	Non-Captured	18.0	1.03 + .004	2.0	2.0	10,000	1000	250	.03 √f(GHz)	670	-(100-fGHz)
	Epoxy Captured	18.0	1.05 + .005	2.0	2.0	10,000	1000	250	.03 √f(GHz)	670	-(60-fGHz)
	Mechanical Capture	18.0	1.04 + .004	2.0	2.0	10,000	1000	250	.03 √f(GHz)	670	-(100-fGHz)
	Field Replaceable Hermetic Launchers	18.0	1.04 + .006	2.0	2.0	10,000	1000	250	.04 √f(GHz)	670	-(100-fGHz)
Bulkhead Feedthrough Jacks	Epoxy Captured	18.0	1.07 + .010	2.0	2.0	10,000	1000	250	.04 √f(GHz)	670	-(60-fGHz)
	Mechanical Capture	18.0	1.07 + .010	2.0	2.0	10,000	1000	250	.04 √f(GHz)	670	-(100-fGHz)
Right-Angle Flange Mount Jacks	N/A	18.0	1.07 + .015	2.0	2.0	10,000	1000	250	.08 √f(GHz)	670	-(90-fGHz)
	N/A	12.4	1.15 + .015	2.0	2.0	10,000	1000	250	.08 √f(GHz)	670	-(90-fGHz)
Printed Circuit Board Mount Straight Terminal	N/A	18.0	N/A	2.0	2.0	10,000	1000	250	N/A	670	N/A
Right-Angle Printed Circuit	N/A	12.4	N/A	2.0	2.0	10,000	1000	250	N/A	670	N/A
End Launch Stripline Circuit	N/A	18.0	1.05 + .005	2.0	2.0	10,000	1000	250	.03 √f(GHz)	670	-(60-fGHz)
Surface Launch Stripline Circuit	N/A	18.0	1.05 + .005	2.0	2.0	10,000	1000	250	.03 √f(GHz)	670	-(60-fGHz)
Right-Angle Surface Launch Stripline Circuit	N/A	12.4	1.15 + .015	2.0	2.0	10,000	1000	250	.08 √f(GHz)	670	-(60-fGHz)
	N/A	18.0	1.07 + .015	2.0	2.0	10,000	1000	250	.08 √f(GHz)	670	-(60-fGHz)

1. Maximum operating frequency of cable per MIL-C-17.
2. Specifications do not apply to hermetic or compression crimp connectors.
3. For Brass SMA: Frequency Range DC-6GHz, Impedance 50 Ohms, Insulation Resistance.

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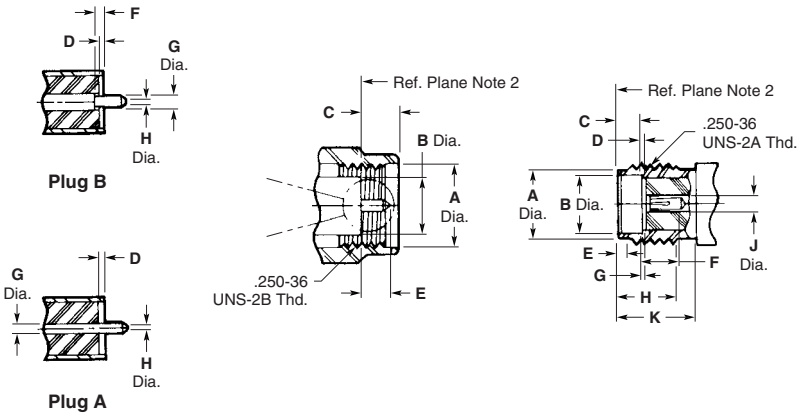
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SMA Connectors (Continued)

Interface Mating Dimensions



Plug

Dimension	Minimum	Maximum
A	**6.35** .250	—
B	—	**4.59** .1808
C	—	**3.43** .135
D	**0.00** .000	**0.25** .010
E	—	**2.54** .100
F	**0.00** .000	**0.25** .010
G	**0.90** .0355	**0.94** .037
H	**0.00** .000	**0.38** .015

Jack

Dimension	Minimum	Maximum
A	**5.28** .208	**5.49** .216
B	**4.60** .181	—
C	**1.91** .075	**1.98** .078
D	**0.00** .000	**0.25** .010
E	**0.38** .015	**1.43** .045
F	**2.92** .115	—
G	**0.00** .000	**0.25** .010
H	**4.32** .170	—
J	**.124** .049	**1.30** .051
K	**5.54** .218	—

Notes:
1. ID to meet VSWR and contact resistance when mated with 0.51 +.025/-.013 [.036 +.0010/-.0005] Dia. Pin.
2. When fully engaged, the two reference planes must coincide with metal to metal contact.
3. Metric equivalents (to the nearest 0.01mm) are given for general information only.

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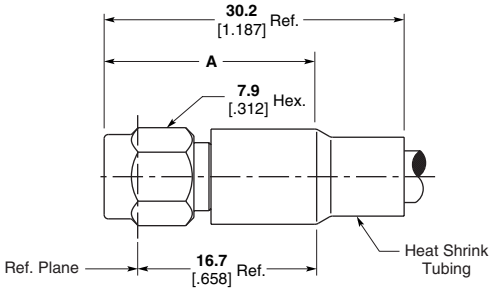
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SMA Connectors (Continued)
Flexible Cable

Straight Cable Plug, Solder



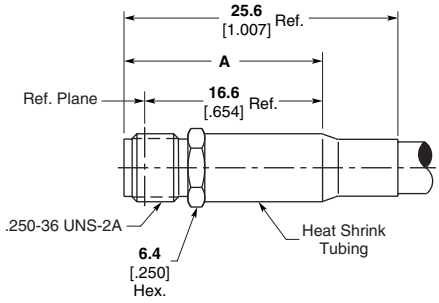


Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Dimension A	Instruction Sheet	Part No.
55, 58, 141, 142, 223, 303, 400	Stainless, Gold[1]	No	Solder	**19.7** .775	408-4821	**1051638-1**
174, 188, 316	Stainless, Gold[1]	No	Solder	**17.5** .690	408-4756	**1051644-1**

[1]Coupling nut is passivated stainless steel.

Straight Cable Jack, Solder

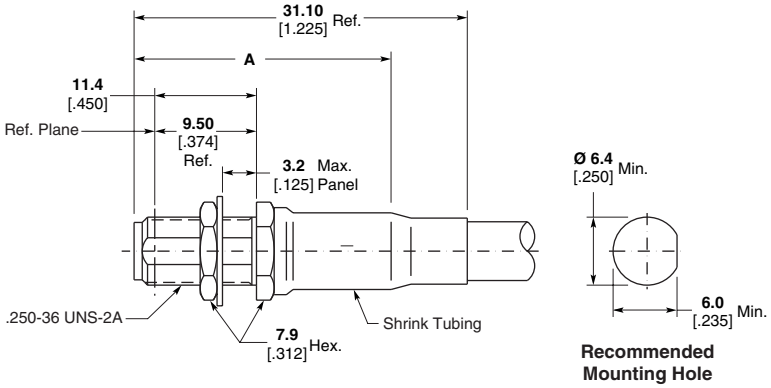




Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Dimension A	Instruction Sheet	Part No.
55, 58, 141, 142, 223, 303, 400	Stainless, Gold	No	Solder	**18.5** .730	408-4820	**1051852-1**

Bulkhead Cable Jack, Solder





Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Dimension A	Instruction Sheet	Part No.
RG 55, 58, 141, 142, 300	Stainless, Gold	No	Solder	**24.0** .945	408-4817	**1051861-1**
174, 188, 316	Stainless, Gold	No	Solder	**21.0** .825	408-4817	**1051942-1**

Note: Part Numbers are RoHS compliant except: ♦ Indicates non-RoHS compliant.

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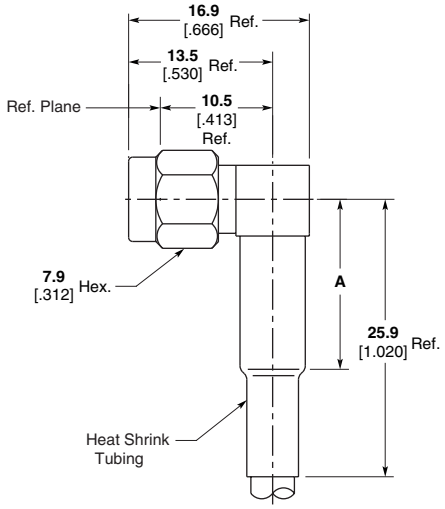
USA: 1-800-522-6752
Canada: 1-905-470-4425
Mexico: 01-800-733-8926
C. America: 52-55-1106-0803

South America: 55-11-2103-6000
Hong Kong: 852-2735-1628
Japan: 81-44-844-8013
UK: 44-8706-080-208

SMA Connectors (Continued)
Flexible Cable (Continued)

Right-Angle Cable Plug, Solder



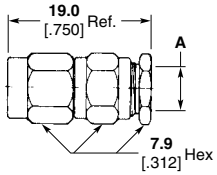


Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Dimension A	Instruction Sheet	Part No.
55, 58, 141, 142, 223, 303, 400	Stainless, Gold[1]	Yes	Solder	**16.0** .630	408-4816	**1052063-1**
174, 188, 316	Stainless, Gold[1]	Yes	Solder	**11.2** .440	408-4815	**1052067-1**

[1]Coupling nut is passivated stainless steel.

Straight Cable Plug, Clamp

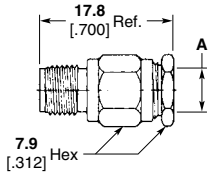




Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Dimension A	Instruction Sheet	Part No.
174, 188, 316	Stainless, Pass.	Yes	Solder	**2.9** .116	408-4906	**1050721-1**

Straight Cable Jack, Clamp





Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Dimension A	Instruction Sheet	Part No.
174, 188, 316	Stainless, Pass.	Yes	Solder	**2.9** .116	408-4906	**1050903-1**

Note: Part Numbers are RoHS compliant except: ♦ Indicates non-RoHS compliant.

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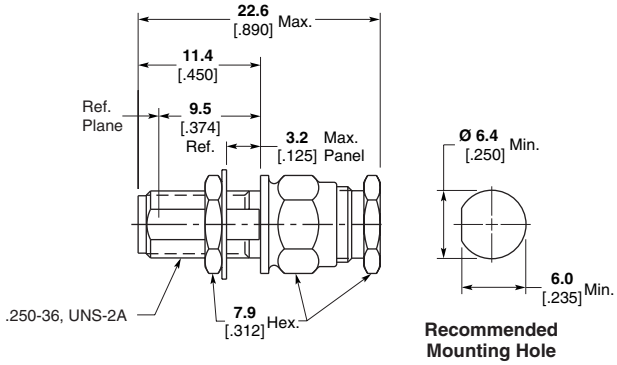
USA: 1-800-522-6752
Canada: 1-905-470-4425
Mexico: 01-800-733-8926
C. America: 52-55-1106-0803

South America: 55-11-2103-6000
Hong Kong: 852-2735-1628
Japan: 81-44-844-8013
UK: 44-8706-080-208

SMA Connectors (Continued)
Flexible Cable (Continued)

Bulkhead Feedthrough Cable Jack, Clamp

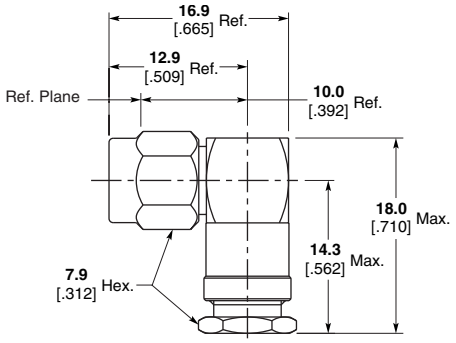




Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Instruction Sheet	Part No.
174, 188, 316	Stainless, Pass.	Yes	Solder	408-4704	**1050996-1**

Right-Angle Cable Plug, Clamp

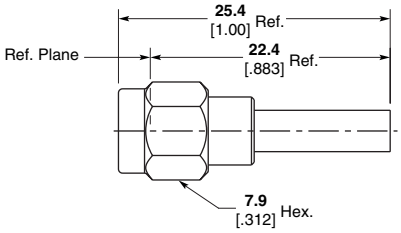




Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Instruction Sheet	Part No.
174, 188, 316	Stainless, Pass.	Mechanical	Solder	408-4965	**1051140-1**

Straight Cable Plug, Crimp





Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Crimp Tooling Part No.	Instruction Sheet	Part No.
174, 179, 187, 188, 316	Stainless, Pass.	Mechanical	Solder/Crimp[2]	1055236-1	408-4661	**1056443-1**
RD316	Stainless, Pass.	Mechanical	Solder/Crimp[2]	1055236-1[1]	408-4661	**1056436-1**
55, 142, 223, 400	Stainless, Pass.	Mechanical	Solder/Crimp[2]	1055236-1	408-4661	**1056438-1**
174, 179, 187, 188, 316	Brass, White Bronze	Mechanical	Solder/Crimp[2]	1055236-1	408-4661	**1082034-1**

[1]Use die 1055270-1 to crimp RD316 ferrule.
[2]Use die 1055880-1 to crimp center contact.

Note: Part Numbers are RoHS compliant except: ♦ Indicates non-RoHS compliant.

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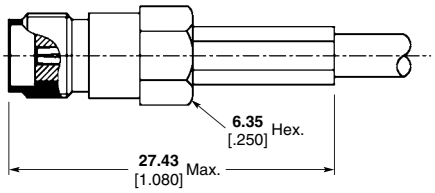
USA: 1-800-522-6752
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Mexico: 01-800-733-8926
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Hong Kong: 852-2735-1628
Japan: 81-44-844-8013
UK: 44-8706-080-208

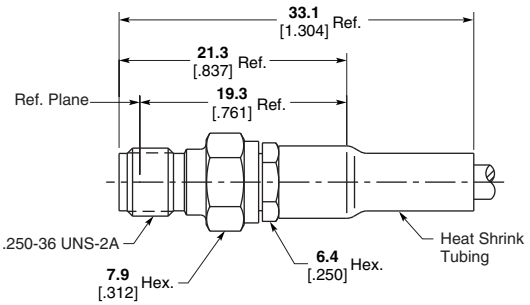
SMA Connectors (Continued)
Flexible Cable (Continued)

Straight Cable Jack, Crimp





Style A



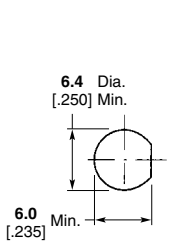
Style B

Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Crimp Tooling Part No.	Instruction Sheet	Style	Part No.
174, 316	Brass, Nickel	Mechanical	Solder	[1]	408-4032	A	**5447648-3**
58, 141, 303	Stainless, Pass.	Mechanical	Solder	1055236-1	408-4704	B	**1051867-1**
174, 188, 316	Stainless, Pass.	Mechanical	Solder	1055236-1	408-4708	B	**1051855-1**
178, 196	Stainless, Pass.	Mechanical	Solder	1055236-1	408-4806	B	**1051869-1**

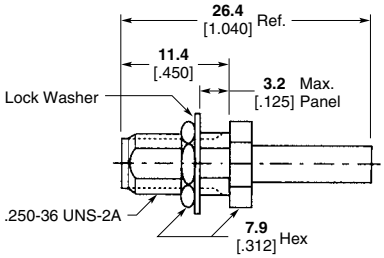
[1]Refer to Tyco Electronics Customer Print for tooling requirement. DANIELS Mil Tooling used for contact and ferrule crimp.

Bulkhead Feedthrough Cable Jack, Crimp





Recommended Mounting Hole



Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Crimp Tooling Part No.	Instruction Sheet	Part No.
174, 179, 187, 188, 316	Stainless, Pass.	Mechanical	Solder/Crimp[2]	1055236-1	408-4661	**1056452-1**
RD316	Stainless, Pass.	Mechanical	Solder/Crimp[2]	1055236-1[3]	408-4661	**1056445-1**
58, 141, 303	Stainless, Pass.	Mechanical	Solder/Crimp[2]	1055236-1	408-4661	**1056450-1**
55, 142, 223, 400	Stainless, Pass.	Mechanical	Solder/Crimp[2]	1055236-1	408-4661	**1056447-1**
174, 188, 316	Brass, Nickel	Mechanical	Crimp	[1]	408-4032	**5448103-2**

[1]Refer to Tyco Electronics Customer Print for tooling requirement. DANIELS Mil Tooling used for contact and ferrule crimp.
[2]Use die 1055880-1 to crimp center contact.
[3]Use die 1055270-1 to crimp RD316 ferrule.

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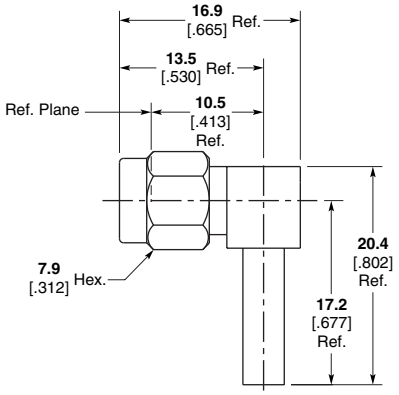
USA: 1-800-522-6752
Canada: 1-905-470-4425
Mexico: 01-800-733-8926
C. America: 52-55-1106-0803

South America: 55-11-2103-6000
Hong Kong: 852-2735-1628
Japan: 81-44-844-8013
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SMA Connectors (Continued)
Flexible Cable (Continued)

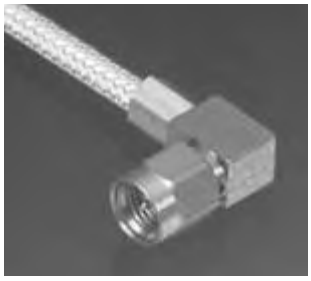
Right-Angle Cable Plug, Crimp

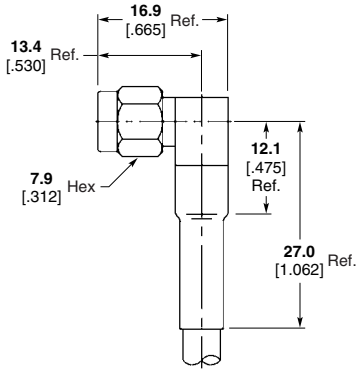




Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Crimp Tooling Part No.	Instruction Sheet	Part No.
174, 179, 187, 188, 316	Stainless, Pass.	Mechanical	Solder	1055236-1	408-4659	**1056462-1**
58, 141, 303	Stainless, Pass.	Mechanical	Solder	1055236-1	408-4659	**1056456-1**

Right-Angle Cable Plug, Crimp





Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Crimp Tooling Part No.	Instruction Sheet	Part No.
55, 142, 223, 400	Stainless, Pass.	Epoxy	Solder	1055236-1	408-4681	**1052072-1**
174, 188, 316	Stainless, Pass.	Epoxy	Solder	1055236-1	408-4683	**1052076-1**
178, 196	Stainless, Pass.	Epoxy	Solder	1055236-1	408-4801	**1052098-1**

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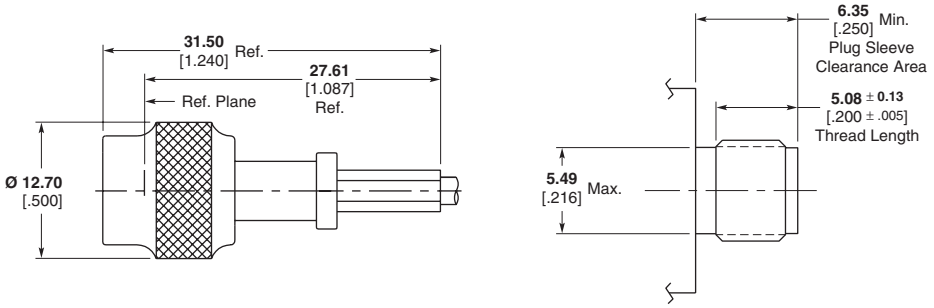
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C. America: 52-55-1106-0803

South America: 55-11-2103-6000
Hong Kong: 852-2735-1628
Japan: 81-44-844-8013
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SMA Connectors (Continued)
Flexible Cable (Continued)

Straight Push-On

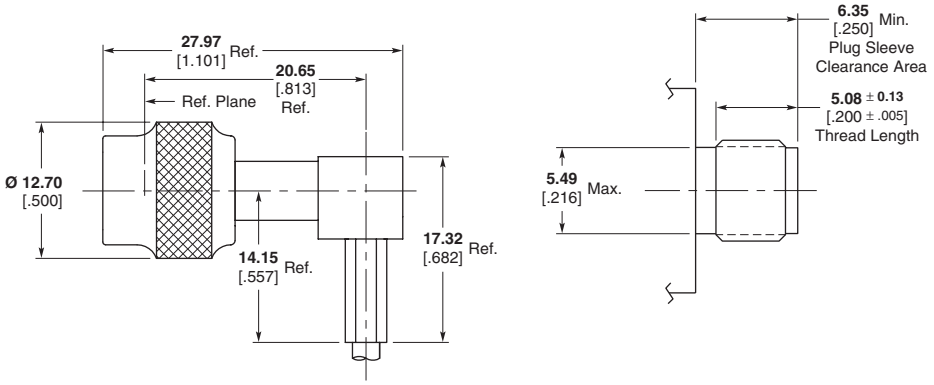




Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Part No.
316	Beryllium Copper, Gold	Mechanical	Crimp	**1408541-1**

Right-Angle Push-On





Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Part No.
316	Beryllium Copper, Gold	Mechanical	Solder/Crimp	**1274694-1**

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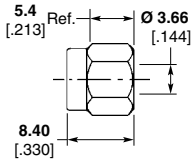
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SMA Connectors (Continued)
Direct Solder Attachment, Semi-Rigid Cable

Straight Cable Plug

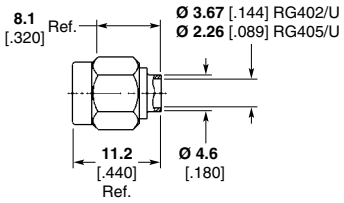




Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Solder Assembly Kit Part No.	Instruction Sheet	Part No.
402 (3.58 [.141])	Stainless, Pass.	No Center Contact	No Center Contact	1055420-1	408-4761	**1050757-1**

Straight Cable Plug



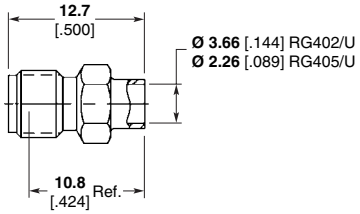


Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Solder Assembly Kit Part No.	Instruction Sheet	Part No.
402 (3.58 [.141])	Stainless, Gold[1]	No	Solder	1055420-1	408-4764	**1050525-1**
405 (2.16 [.085])	Stainless, Gold[1]	No	Solder	1055420-1	408-4765	**1050770-1**
402 (3.58 [.141])	Stainless, Gold[1]	No Center Contact	No Center Contact	N/A	—	**1050542-1**
405 (2.16 [.085])	Stainless, Gold[1]	No	Solder	1055420-1	—	**1050548-1**

[1]Coupling nut is passivated stainless steel.

Straight Cable Jack





Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Solder Assembly Kit Part No.	Instruction Sheet	Part No.
402 (3.58 [.141])	Stainless, Gold	No	Solder	1055420-1	408-4767	**1050854-1**
405 (2.16 [.085])	Stainless, Gold	No	Solder	1055420-1	408-4833	**1050859-1**

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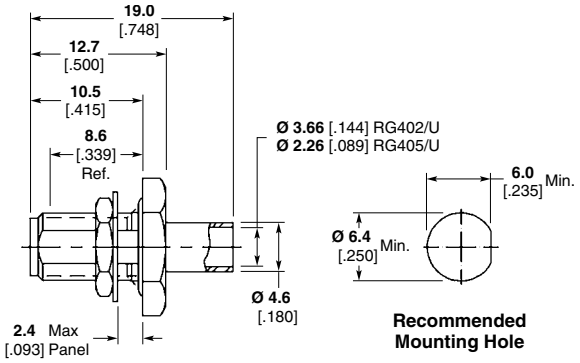
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SMA Connectors (Continued)
Direct Solder Attachment, Semi-Rigid Cable (Continued)

Bulkhead Cable Jack

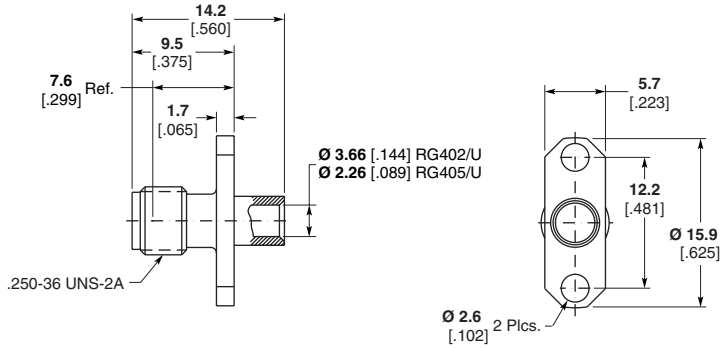




Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Solder Assembly Kit Part No.	Instruction Sheet	Part No.
402 (3.58 [.141])	Brass, Gold	No	Solder	1055420-1	408-4768	**1082029-1**

2 Hole Flange Mount Cable Jack

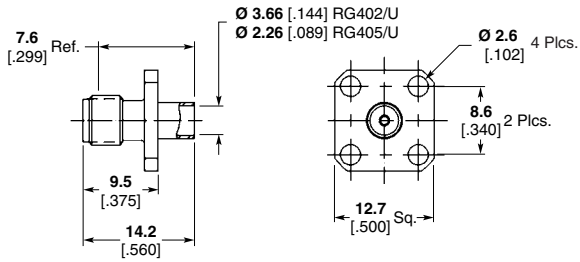




Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Solder Assembly Kit Part No.	Instruction Sheet	Part No.
402 (3.58 [.141])	Stainless, Gold	No	Solder	1055420-1	408-4767	**1051052-1**
405 (2.16 [.085])	Stainless, Gold	No	Solder	1055420-1	408-4883	**1051046-1**

4 Hole Flange Mount Cable Jack





Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Solder Assembly Kit Part No.	Instruction Sheet	Part No.
402 (3.58 [.141])	Stainless, Gold	No	Solder	1055420-1	408-4767	**1051081-1**
405 (2.16 [.085])	Stainless, Gold	No	Solder	1055420-1	408-4883	**1051085-1**

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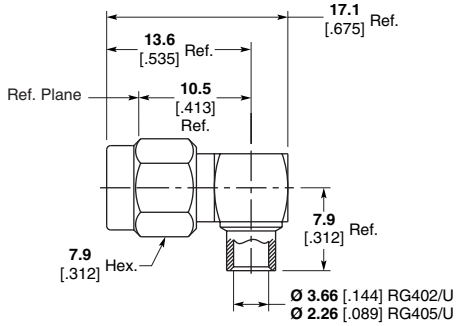
USA: 1-800-522-6752
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Japan: 81-44-844-8013
UK: 44-8706-080-208

SMA Connectors (Continued)
Semi-Rigid Cable

Right-Angle Cable Plug, Direct Solder Attachment



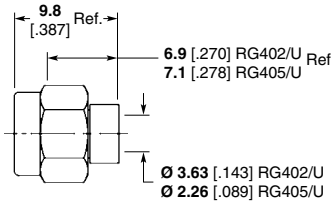


Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Solder Assembly Kit Part No.	Instruction Sheet	Part No.
402 (3.58 [.141])	Stainless, Gold[1]	Epoxy	Solder	1055420-1	408-4831	**1051151-1**
405 (2.16 [.085])	Stainless, Gold[1]	Epoxy	Solder	1055420-1	408-4831	**1051157-1**
405 (2.16 [.085])	Brass, Gold	Mechanical	Solder	1055420-1	408-4831	**1088312-1**

[1]Coupling nut is passivated stainless steel.

Straight Cable Plug, Crimp

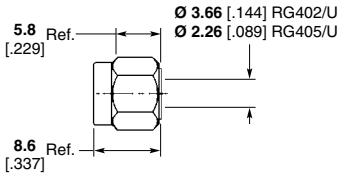




Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Crimp Tooling Part No.	Instruction Sheet	Part No.
405 (2.16 [.085])	Stainless, Pass.	Mechanical	Solderless	1055835-1	408-4695	**1050598-1**
402 (3.58 [.141])	Stainless, Pass.	No Center Contact	Solderless	1055835-1	408-4690	**1050740-1**

Straight Cable Plug — Low Profile, Crimp





Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Crimp Tooling Part No.	Instruction Sheet	Part No.
402 (3.58 [.141])	Stainless, Pass.	Mechanical	Solderless	1055835-1	408-4696	**1050602-1**
405 (2.16 [.085])	Stainless, Pass.	Mechanical	Solderless	1055835-1	408-4697	**1050611-1**

Note: Part Numbers are RoHS compliant except: ♦ Indicates non-RoHS compliant.

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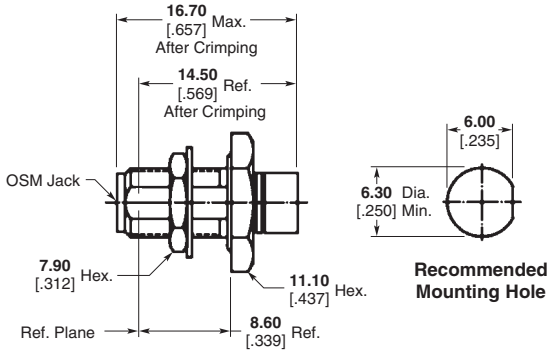
USA: 1-800-522-6752
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Japan: 81-44-844-8013
UK: 44-8706-080-208

SMA Connectors (Continued)
Semi-Rigid Cable (Continued)

2 Hole Flange, Crimp

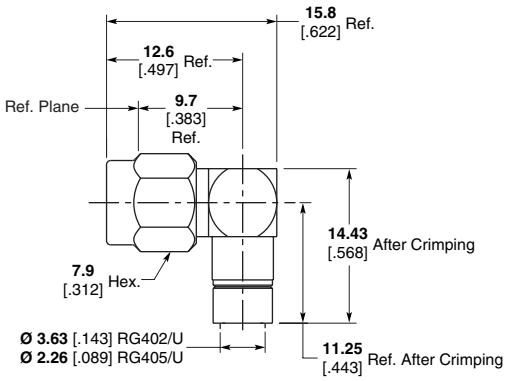




Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Crimp Tooling Part No.	Instruction Sheet	Part No.
402 (3.58 [.141])	Stainless, Pass.	Mechanical	Solderless	1055835-1	408-4954	**1051005-1**
405 (2.16 [.085])	Stainless, Pass.	Mechanical	Solderless	1055835-1	408-4689	**1051007-1**

Right-Angle Cable Plug, Crimp





Cable Type RG/U	Body Material & Finish	Contact Captivation	Contact Attachment	Crimp Tooling Part No.	Instruction Sheet	Part No.
402 (3.58 [.141])	Stainless, Pass.	Mechanical	Solderless	1055835-1	408-4691	**1051145-1**
405 (2.16 [.085])	Stainless, Pass.	Mechanical	Solderless	1055835-1	408-4692	**1051147-1**

Note: Part Numbers are RoHS compliant except: ♦ Indicates non-RoHS compliant.

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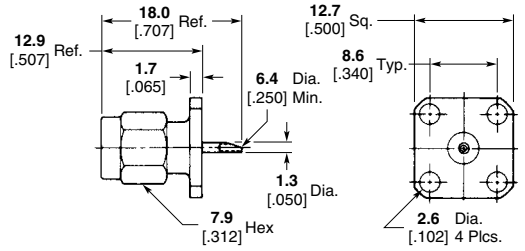
USA: 1-800-522-6752
Canada: 1-905-470-4425
Mexico: 01-800-733-8926
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South America: 55-11-2103-6000
Hong Kong: 852-2735-1628
Japan: 81-44-844-8013
UK: 44-8706-080-208

SMA Connectors (Continued)
Panel Mount, Solder Pot Terminal

4 Hole Flange Mount Plug Receptacle

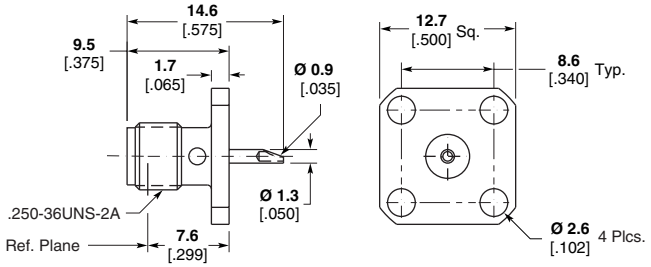




Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	N/A	-65 to 125° C	**1052324-1**

4 Hole Flange Mount Jack Receptacle

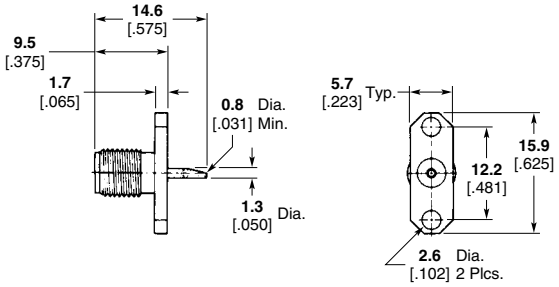




Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	-(60-fGHz)	-65 to 125° C	**1052422-1**

2 Hole Flange Mount Jack Receptacle

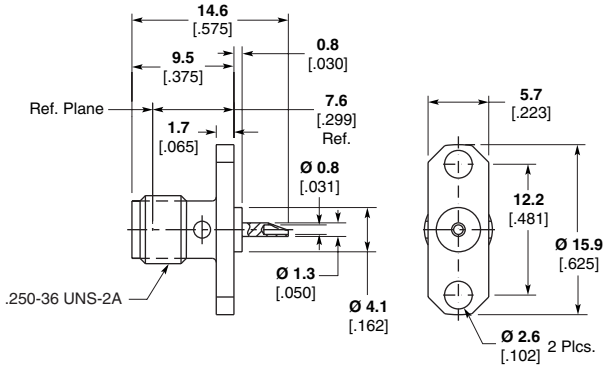




Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	-(60-fGHz)	-65 to 125° C	**1052544-1**

2 Hole Flange Mount Jack Receptacle





Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	-(60-fGHz)	-65 to 125° C	**1052534-1**

Note: Part Numbers are RoHS compliant except: ♦ Indicates non-RoHS compliant.

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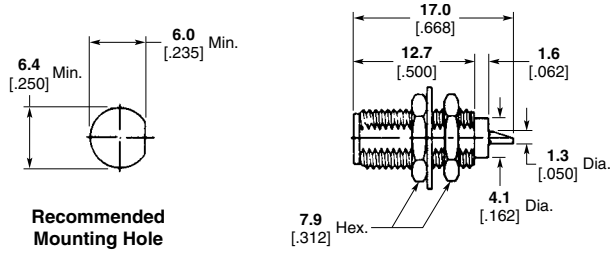
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Hong Kong: 852-2735-1628
Japan: 81-44-844-8013
UK: 44-8706-080-208

SMA Connectors (Continued)
Panel Mount

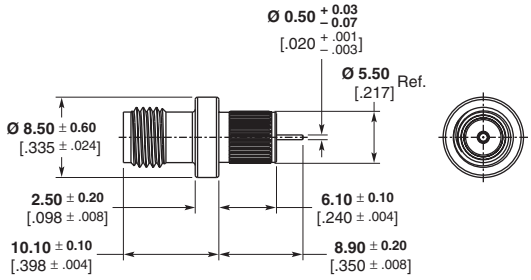
Bulkhead Feedthrough Jack Receptacle, Solder Pot Terminal



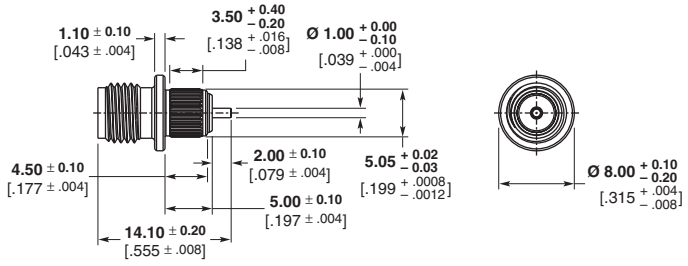


Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	N/A	-65 to 125° C	**1053092-1**

Press-In Jacks, Straight Terminal



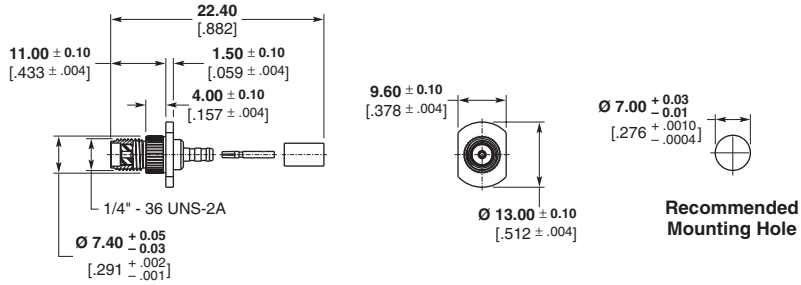
Part Number 1460468



Part Number 1460469

Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Brass, White Bronze	Mechanical	N/A	–65 to 125° C	**1460468-1**
Brass, Gold	Mechanical	N/A	–65 to 125° C	**1460469-1**

Press-In Cable, Jack Panel



Cable Type RG/U	Body Material & Finish	Contact Captivation	Temperature Range	Part No.
316 D	Brass, Gold	Mechanical	–65 to 125° C	**619115-1**

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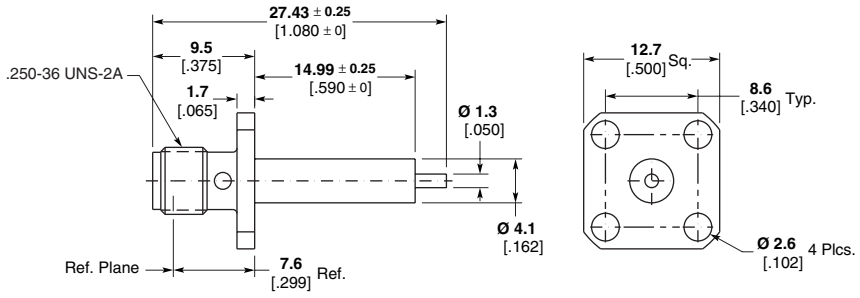
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SMA Connectors (Continued)
Panel Mount, Straight Terminal

4 Hole Flange Mount Jack Receptacle

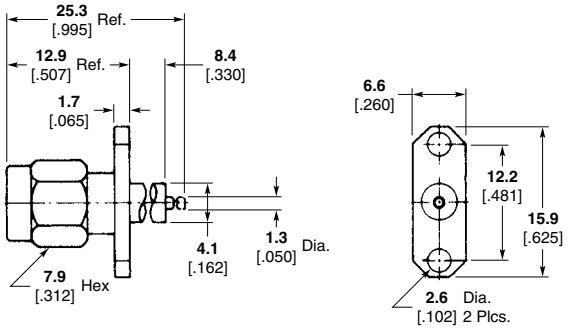




Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	None	-(100-fGHz)	-65 to 165° C	**1052518-1**
Stainless, Passivated	Epoxy	-(60-fGHz)	-65 to 125° C	**1052523-1**
Stainless, Gold	Epoxy	-(60-fGHz)	-65 to 125° C	**1052522-1**

2 Hole Flange Mount Plug Receptacle

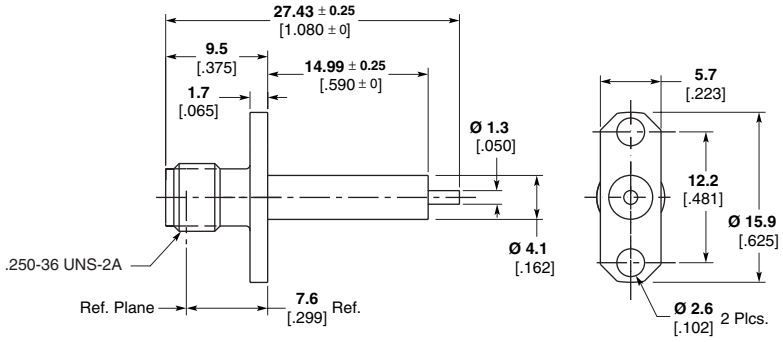




Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	-(60-fGHz)	-65 to 125° C	**1052349-1**

2 Hole Flange Mount Jack Receptacle





Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	-(60-fGHz)	-65 to 125° C	**1052552-1**

Note: Part Numbers are RoHS compliant except: ♦ Indicates non-RoHS compliant.

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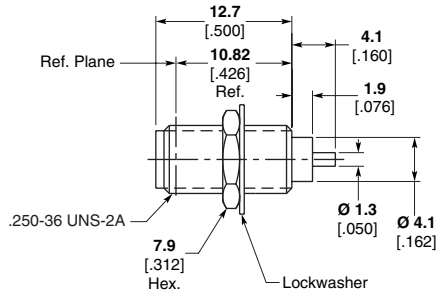
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Hong Kong: 852-2735-1628
Japan: 81-44-844-8013
UK: 44-8706-080-208

SMA Connectors (Continued)
Panel Mount, Straight Terminal (Continued)

Bulkhead Feedthrough Jack Receptacle

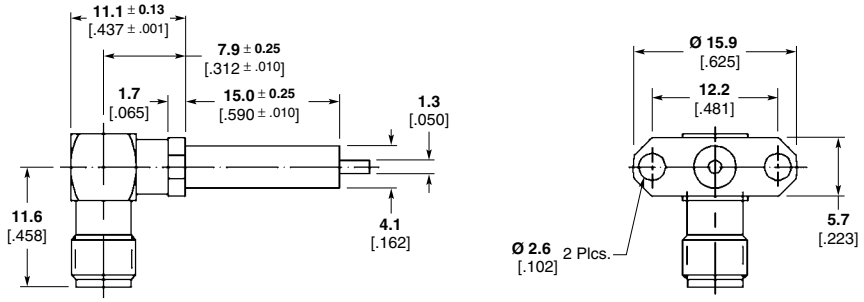




Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	-(60-fGHz)	-65 to 125° C	**1053222-1**

2 Hole Flange Mount Right-Angle Jack Receptacle

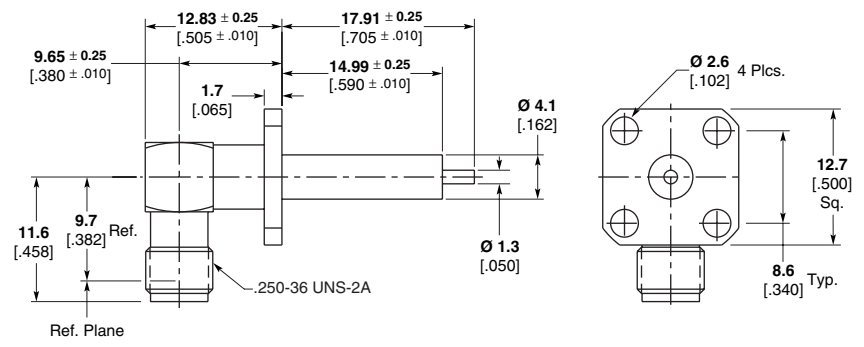




Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Mechanical	-(90-fGHz)	-65 to 165° C	**1052986-1**

4 Hole Flange Mount Right-Angle Jack Receptacle





Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Mechanical	-(90-fGHz)	-65 to 165° C	**1052978-1**
Stainless, Passivated	Mechanical	-(90-fGHz)	-65 to 165° C	**1052982-1**

Note: Part Numbers are RoHS compliant except: ♦ Indicates non-RoHS compliant.

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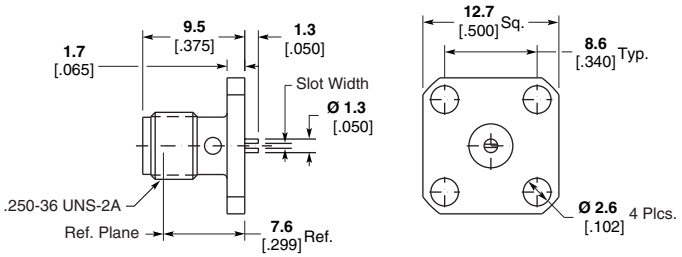
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C. America: 52-55-1106-0803

South America: 55-11-2103-6000
Hong Kong: 852-2735-1628
Japan: 81-44-844-8013
UK: 44-8706-080-208

SMA Connectors (Continued)
Panel Mount

4 Hole Flange Mount Jack Receptacle, Straight Terminal

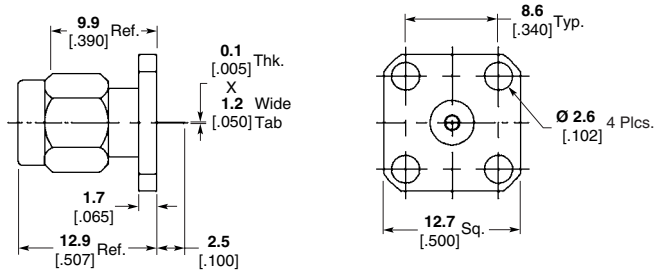




Body Material & Finish	Contact Captivation	Slot Width +.076/-.025 [+.003/-.001]	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	0.5 [.018]	-(60-fGHz)	-65 to 125° C	**1052563-1**

4 Hole Flange Mount Plug Receptacle, Tab Terminal

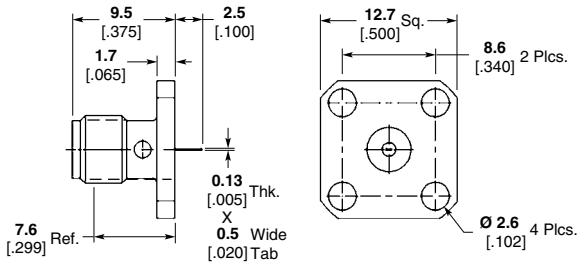




Body Material & Finish	Contact Captivation	Tab Width	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	1.3 [.050]	-(60-fGHz)	-65 to 125° C	**1052360-1**

4 Hole Flange Mount Jack Receptacle, Tab Terminal





Body Material & Finish	Contact Captivation	Tab Width	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	.51 [.020]	-(60-fGHz)	-65 to 125° C	**1052898-1**

Note: Part Numbers are RoHS compliant except: ♦ Indicates non-RoHS compliant.

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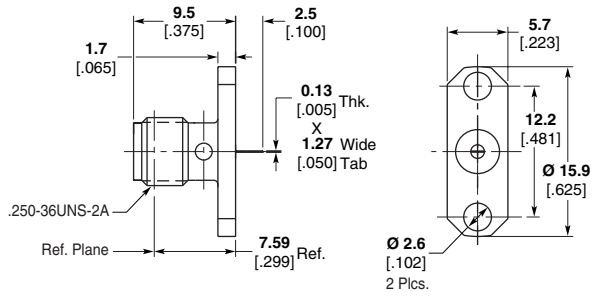
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Mexico: 01-800-733-8926
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South America: 55-11-2103-6000
Hong Kong: 852-2735-1628
Japan: 81-44-844-8013
UK: 44-8706-080-208

SMA Connectors (Continued)

2 Hole Flange Mount Jack Receptacle, Panel Mount, Tab Terminal

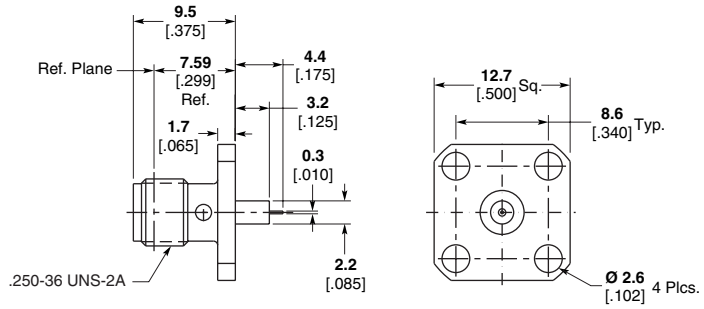




Body Material & Finish	Contact Captivation	Horizontal Tab	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	✓	-(60-fGHz)	-65 to 125° C	**1052577-1**

4 Hole Flange Mount Jack Receptacle, for Microstrip Transmission Line Circuits

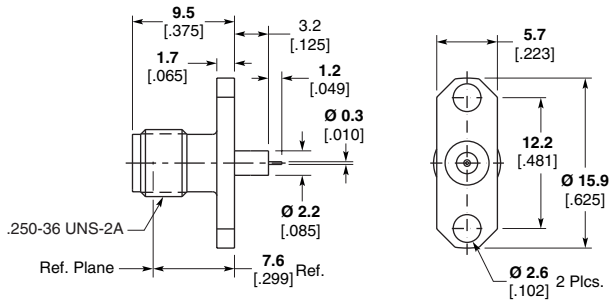




Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	-(60-fGHz)	-65 to 125° C	**1052528-1**

2 Hole Flange Mount Jack Receptacle, for Microstrip Transmission Line Circuits





Body Material & Finish	Contact Captivation	RF Leakage db min.	Temperature Range	Part No.
Stainless, Passivated	Epoxy	-(60-fGHz)	-65 to 125° C	**1052902-1**

Note: Part Numbers are RoHS compliant except: ♦ Indicates non-RoHS compliant.

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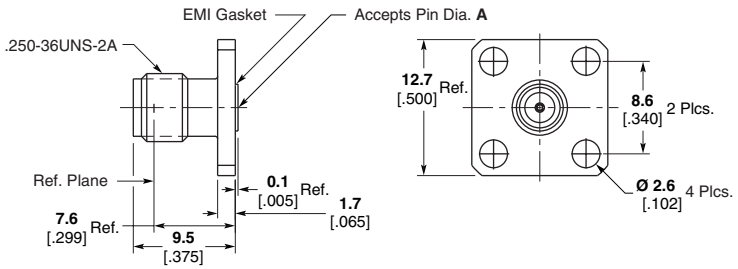
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South America: 55-11-2103-6000
Hong Kong: 852-2735-1628
Japan: 81-44-844-8013
UK: 44-8706-080-208

SMA Connectors (Continued)
Field Replaceable Hermetic Launchers (Continued)

4 Hole Flange Mount Jack Receptacle with EMI/RFI Gasket

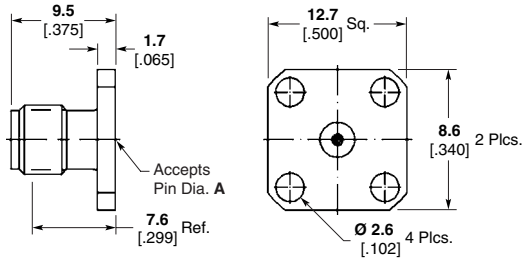




Material & Finish	Captivation	Pin Diameter A	Part No.
Stainless, Passivated	Mechanical	.38 [.015]	**1052684-1**

4 Hole Flange Mount Jack Receptacle without EMI/RFI Gasket

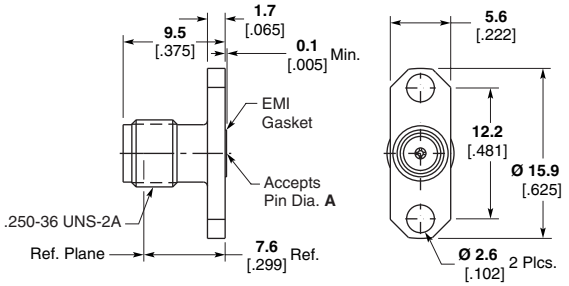




Material & Finish	Captivation	Pin Diameter A	Part No.
Stainless, Passivated	Mechanical	.91 [.036]	**1052643-1**

2 Hole Flange Mount Jack Receptacle with EMI/RFI Gasket

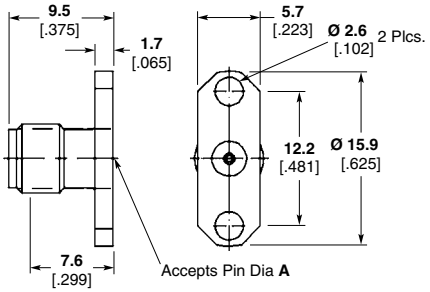




Material & Finish	Captivation	Pin Diameter A	Part No.
Stainless, Passivated	Mechanical	.30 [.012]	**1052628-1**
Stainless, Passivated	Mechanical	.38 [.015]	**1052689-1**
Stainless, Passivated	Mechanical	.46 [.018]	**1052634-1**

2 Hole Flange Mount Jack Receptacle without EMI/RFI Gasket, Field Replaceable Hermetic Launchers





Material & Finish	Captivation	Pin Diameter A	Part No.
Stainless, Passivated	Mechanical	.51 [.020]	**1052652-1**
Stainless, Passivated	Mechanical	.91 [.036]	**1052646-1**

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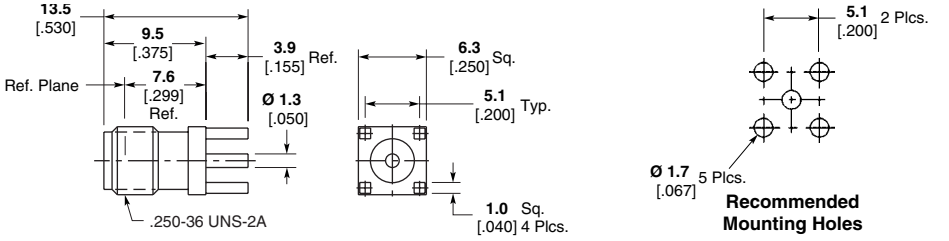
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Mexico: 01-800-733-8926
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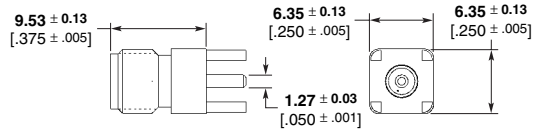
SMA Connectors (Continued)

PC Board Mount Vertical Jack

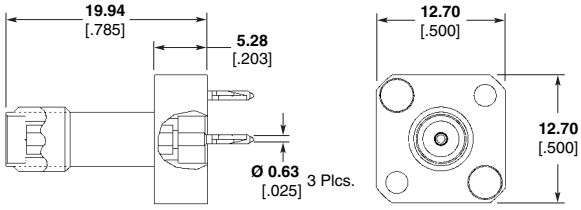




Style 1



Style 2

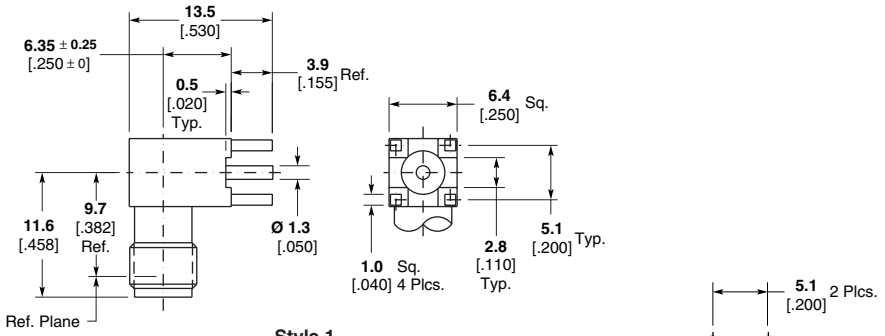


Style 3

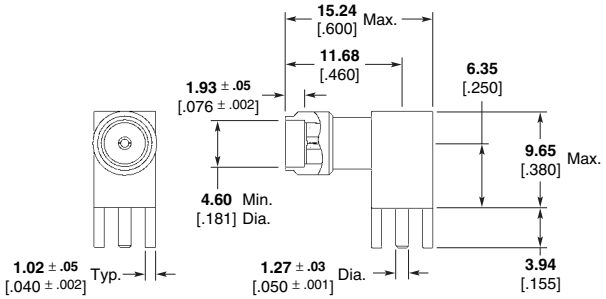
Material & Finish	Style No.	Part No.
Stainless, Gold	1	**1053354-1**
Brass, Gold	2	**221789-1**
Brass, Gold	2	**221789-3**
Brass, Nickel Plate	3	**6274096-1**

PC Board Mount Right-Angle Jack





Style 1



Style 2

Material & Finish	Style No.	Part No.
Stainless, Gold	1	**1053378-1**
Stainless, Gold	2	**221790-1**

Note: Part Numbers are RoHS compliant except: ♦ Indicates non-RoHS compliant.

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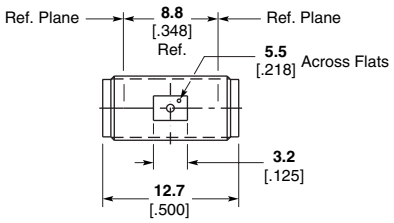
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South America: 55-11-2103-6000
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SMA Connectors (Continued)

In-Series Adapter, Jack to Jack

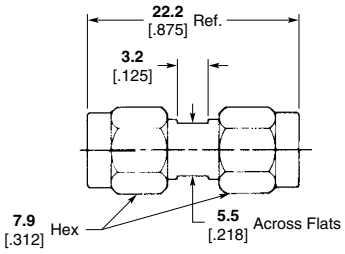




Frequency	Material & Finish	Captivation	Part No.
DC-18.0GHz	Stainless, Gold	Epoxy*	**1053488-1**

In-Series Adapter, Plug to Plug



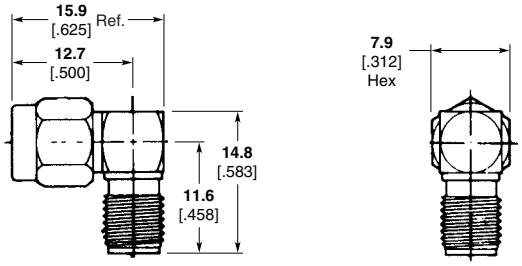


Frequency	Material & Finish	Captivation	Part No.
DC-18.0GHz	Stainless, Passivated	Epoxy*	**1053635-1**

*All adapters listed above employ epoxy captivation. Mechanically captivated versions are also available. Please consult Tyco Electronics.

In-Series Adapter, Jack to Plug, Right-Angle

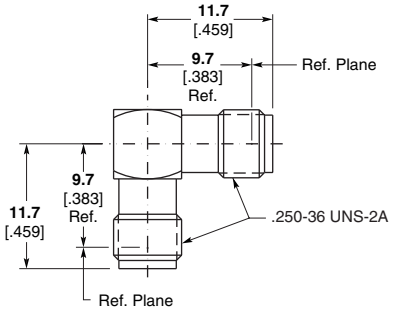




Frequency	Material & Finish	Captivation	Part No.
DC-12.4GHz	Stainless, Passivated	Mechanical	**1055065-1**

In-Series Adapter, Jack to Jack, Right-Angle





Frequency	Material & Finish	Captivation	Part No.
DC-12.4GHz	Stainless, Passivated	Mechanical	**1055018-1**

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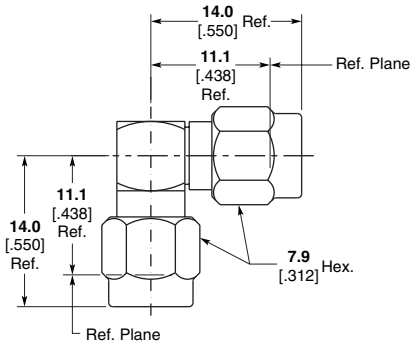
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South America: 55-11-2103-6000
Hong Kong: 852-2735-1628
Japan: 81-44-844-8013
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SMA Connectors (Continued)

In-Series Adapter, Plug to Plug, Right-Angle

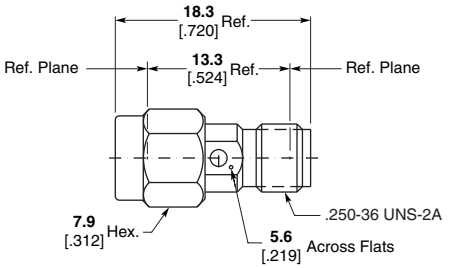




Frequency	Material & Finish	Captivation	Part No.
DC-18.0GHz	Stainless, Passivated	Mechanical	**1055047-1**

In-Series Adapter, Jack to Plug, Connector Saver

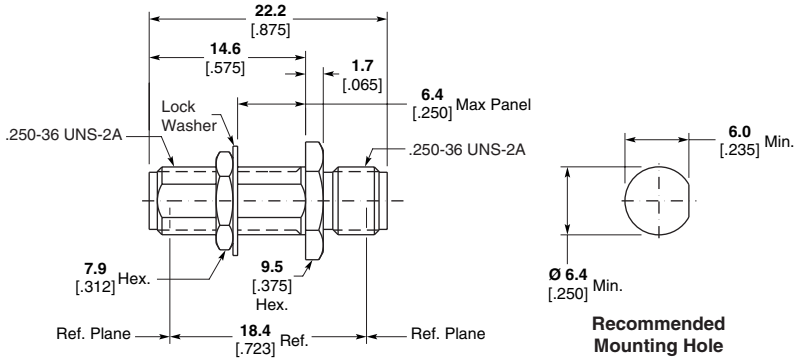




Frequency	Material & Finish	Captivation	Part No.
DC-18.0GHz	Stainless, Passivated	Epoxy	**1054426-1**

In-Series Adapter, Jack to Jack, Bulkhead Feedthrough

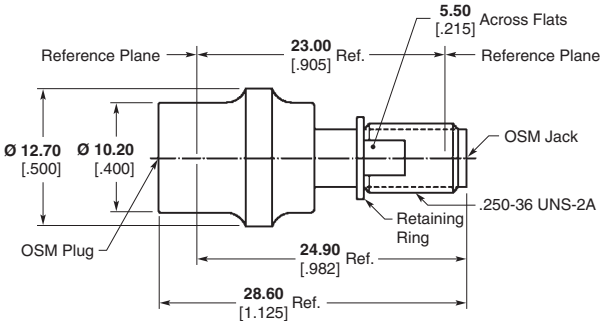




Frequency	Material & Finish	Captivation	Part No.
DC-18.0GHz	Stainless, Passivated	Epoxy*	**1054869-1**

*Mechanically captivated version available. Please consult Tyco Electronics.

Test Adapter, Plug to Jack, Quick Release



Frequency	Material & Finish	Captivation	Part No.
DC-18.0GHz	Stainless, Passivated	Epoxy	**1053780-1**

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RLC Circuits – Building An AM Radio





(Left) An AM radio station antenna tower; (Right) A circuit that tunes for AM frequencies. You will build this circuit in lab to receive AM transmissions from towers such as the one on the left.

Objective: To understand how AM radio waves are produced and encoded. To learn how information is carried by a radio wave. To realize how radio waves are detected and decoded by building a working, tunable AM radio from an RLC (resistor-inductor-capacitor) circuit.

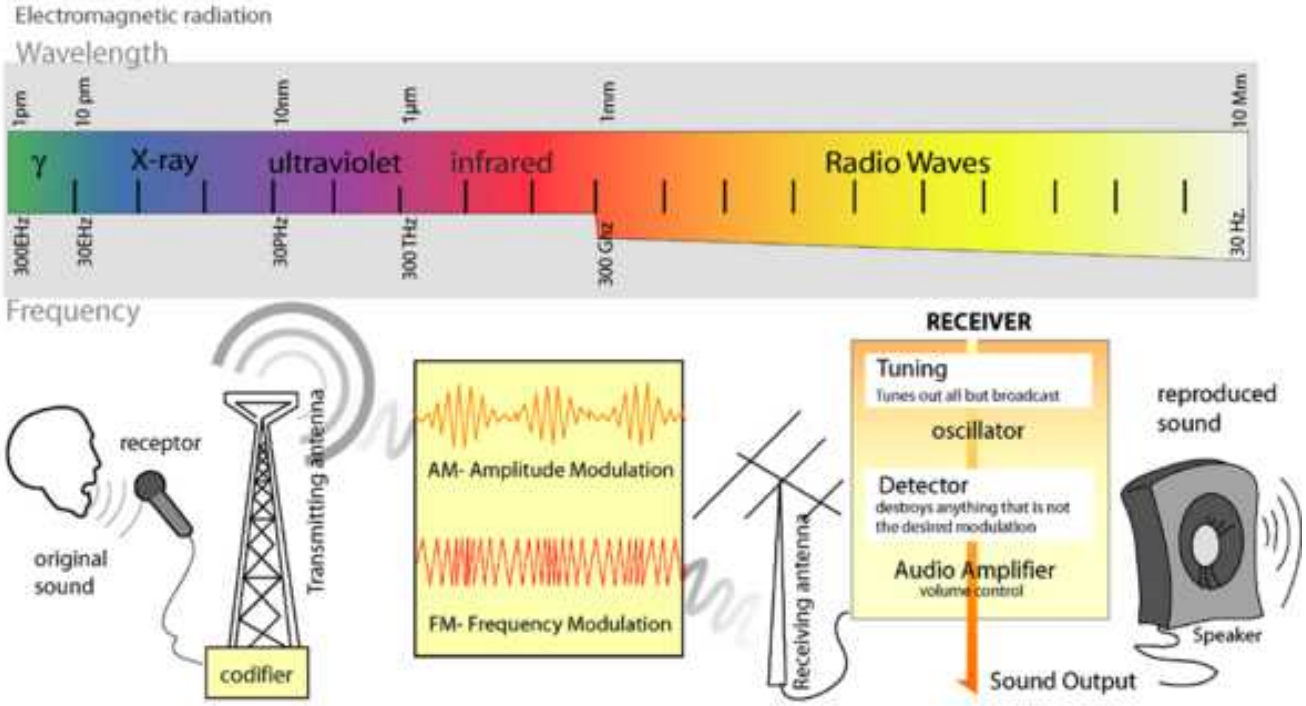
Apparatus: SnapCircuits board, circuit elements (resistors, inductor "A1", capacitors C2 & CV, inductor/antenna A1, amplifier U5), PC speakers, PC sound card interface, FFTScope software, battery (two AA), banana-to-button cables (3), banana-to-banana "jumper" cables (2), earphones (if available)

Introduction

Earlier this semester you created electric fields by transferring charges (from friction and electrostatic induction). You also employed circuits to light up bulbs, create magnetic fields, and run electric motors. In this lab you will build a circuit to detect radio waves, which are used in every form of wireless communication – radio broadcasts, WiFi networks, cell phones, Bluetooth...even garage door openers and keyless car remotes. Radio waves belong to the portion of the electromagnetic spectrum which has the longest wavelengths. Note that this also corresponds to the lowest frequencies, since the product of the wavelength and frequency of these waves equals the speed of light:

$$c = f\lambda = 3\,x\,10^{8}\,m/s$$

In the top part of the illustration below you will see that there are many other forms of electromagnetic radiation – examples are microwaves from your oven (12 cm wavelength), light (400-nm wavelength), x-rays at the doctor's office (10 Angstroms), and over-the-air television (1 m wavelength). Note that AM radio waves (frequency 530-1650 kHz, check your radio) have wavelengths between 180-570 meters; this requires a large antenna to transmit waves of this dimension – see the very tall tower at the beginning of this write-up.



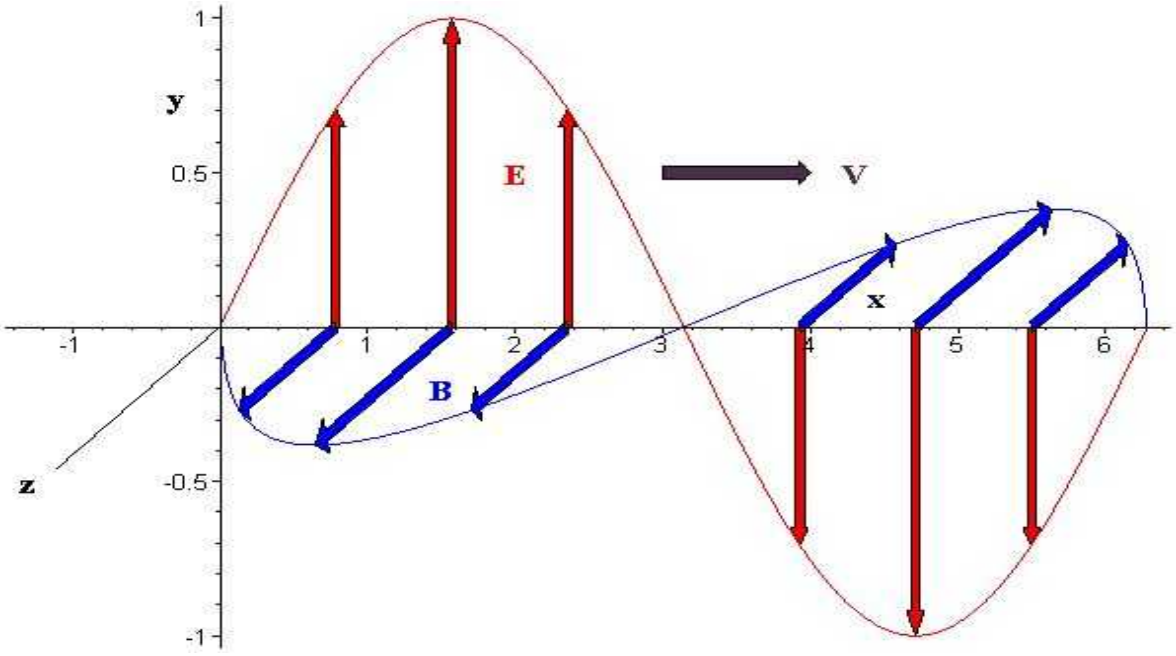
At the the bottom of the illustration above is a pictorial representation of how an AM broadcast travels from the station to your radio (left to right). Note the distinction between AM (amplitude modulation) and FM (frequency modulation) in the middle of the pictorial representation – a steady wave conveys no information unless it is *modulated*, which means that the waveform is varied slightly to transmit information. In AM, the amplitude is varied to carry the audio information (like transverse wave pulses); in FM, the frequency is varied instead (like longitudinal wave pulses).

You will be building the RECEIVER, which receives the signal from the antenna, tunes to the desired frequency/wavelength, filters out any extraneous information, and amplifies it so that it can be reproduced by a speaker. At the very heart of the AM receiver is an RLC circuit which responds to a particular frequency that is a function of its capacitance C and inductance L. To understand C and L it is often useful to think of mechanical systems, such as a mass suspended from a spring bouncing up and down while submerged in a fluid. Here, the capacitance is analogous to a *spring's strength* in a mechanical system while inductance is analogous to *mass*. The resistance is analogous to the *drag* or *friction* in the fluid. These will be discussed further in the Theory section below.

Theory

Electromagnetic Waves

Electromagnetic (EM) waves are self-propagating waves that travel through space (without the need for a medium, like ocean waves require water or sound waves require air) and have an electrical (**E**-field) and magnetic (**B**-field) component that are in phase with each other. These components are perpendicular to each other, and are both perpendicular to the direction of wave propagation, as shown in the graphic below.



See this link (http://www.phys.hawaii.edu/~teb/java/ntnujava/emWave/emWave.html) for a java applet that animates the above (press the Start button after you note the initial directions of the **E** and **B** vectors). Note that the directions of **E**, **B**, and **v** are related by the right-hand rule – point your fingers in the direction of **E**, sweep it into the direction of **B** and your outstretched thumb should determine the direction of **v**. The wave travels at the speed of light, as predicted by James Clark Maxwell. In fact, the magnitudes of **E**, **B**, and c (speed of light) are intimately related by the following equation:

$$E = cB$$

You may have learned in previous labs (or in lecture) that a changing B-field gives rise to a changing E-field, and vice versa – this is how an electric generator (and it's inverse, the electric motor) works. According to Maxwell's Equations, this continuous sequence of changing **B** giving rise to changing **E** which in turn gives rise to changing **B** (and so on) sustains itself, forming a self-propagating wave. EM waves carry energy and momentum. You can feel this energy when light from the sun arrives at your skin on a sunny day. *Solar sailing* is a proposed method of propulsion that uses the momentum

imparted by sunlight on large membranes tethered to spacecraft to travel away from the sun.

How are EM waves produced? The simplest way is to take a charge and shake it. Imagine the E-field lines on the charge (radially outward, if it's a positive charge) *before* you shake it. Now, moving the charge back and forth with an up-and-down harmonic motion will put pulses on these field lines (just as shaking a long bungee cord will produce pulses on it). These pulses travel at the speed of light. Note that "shaking" the charge means continually accelerating it – it is not enough to move a charge a constant velocity (which will indeed produce a B-field); you must move it with changing velocity so that it produces a *changing* B-field, which in turns produces a changing E-field, etc. You can see such the production of an EM wave in this java applet (don't forget to click and drag to rotate the wave, especially almost edge-on so you can see it coming towards you!) :

http://micro.magnet.fsu.edu/primer/java/polarizedlight/emwave/index.html

Note that the axis along which the charge moves up and down is the direction of *polarization*. This is also the direction of the E-field. We usually say that the the wave is polarized in a particular direction (say, the y-direction) if its E-field oscillates in that direction.

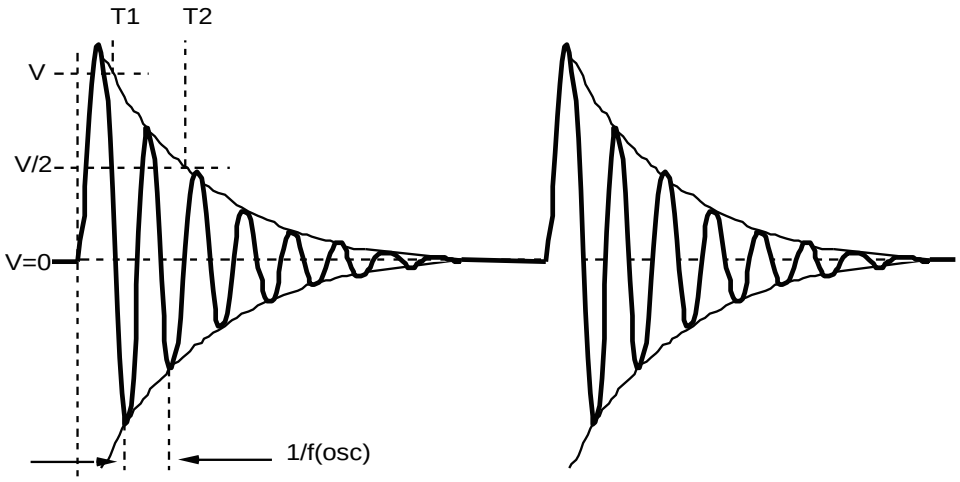
Now, picking up a charge and shaking it manually is impractical, so we try to do it electronically – by varying the direction and magnitude of current in a wire sinusoidally, for example. A device that can do this wave-sending is an RLC circuit attached to an antenna (where the charges move back and forth). Interestingly, the same type of RLC circuit at the same frequency (connected to an antenna) is used to receive the wave at a distant location. We will now learn a little about RLC circuits.

RLC Circuits

The voltage across a charged capacitor discharging through a resistor obeys the law:

$V = V_0 e^{-t/\tau_C}$ where $\tau_C = RC$ is the decay constant related to the half-time

When an inductor is connected in series with the capacitor, the energy is shuttled back and forth between the two (electrical energy & magnetic energy) resulting in an oscillation. This is akin, using the mechanical analogy, to a mass on a spring oscillating back and forth while energy is converted from kinetic to potential and back again. If the system did not dissipate energy through the resistor it would oscillate forever, much like a mass sliding on a frictionless track, attached to a spring. However, due to resistance, the oscillation is damped and dies out eventually within each pulse cycle (see figure below).



The charge on one of the capacitor plates is given by

$$Q = Q_0 e^{-t/\tau_{RLC}} \cos \omega_0 t$$

where $\omega_0 = 2\pi f_0 = \frac{2\pi}{T} = \sqrt{\frac{1}{LC}}$ and $\tau_{RLC} = \frac{2L}{R}$

Note that there are now two time parameters - ω_0 , the oscillation frequency for natural (undriven) oscillation and τ_{RLC} , the decay constant for amplitude damping. In the figure above, τ_{RLC} determines how steeply the wave's outer envelope decreases, while ω_0 determines how quickly the wave inside the outer envelop oscillates.

The frequency ω_0 is important in nature because it is the *resonant frequency* of a system. You will most easily pump energy into a system if you drive it at its resonant frequency. For instance, you already know that to increase the swinging amplitude of a person on a swing, you should push at the same rate they are oscillating, otherwise the pushing might actually decrease the swinging amplitude. Also, it is not enough to push with the same frequency; one should also push with the same *phase*, or place in the wave cycle - you wouldn't push the swing when it is making its way back to you but rather when it's moving away from you.

Procedure

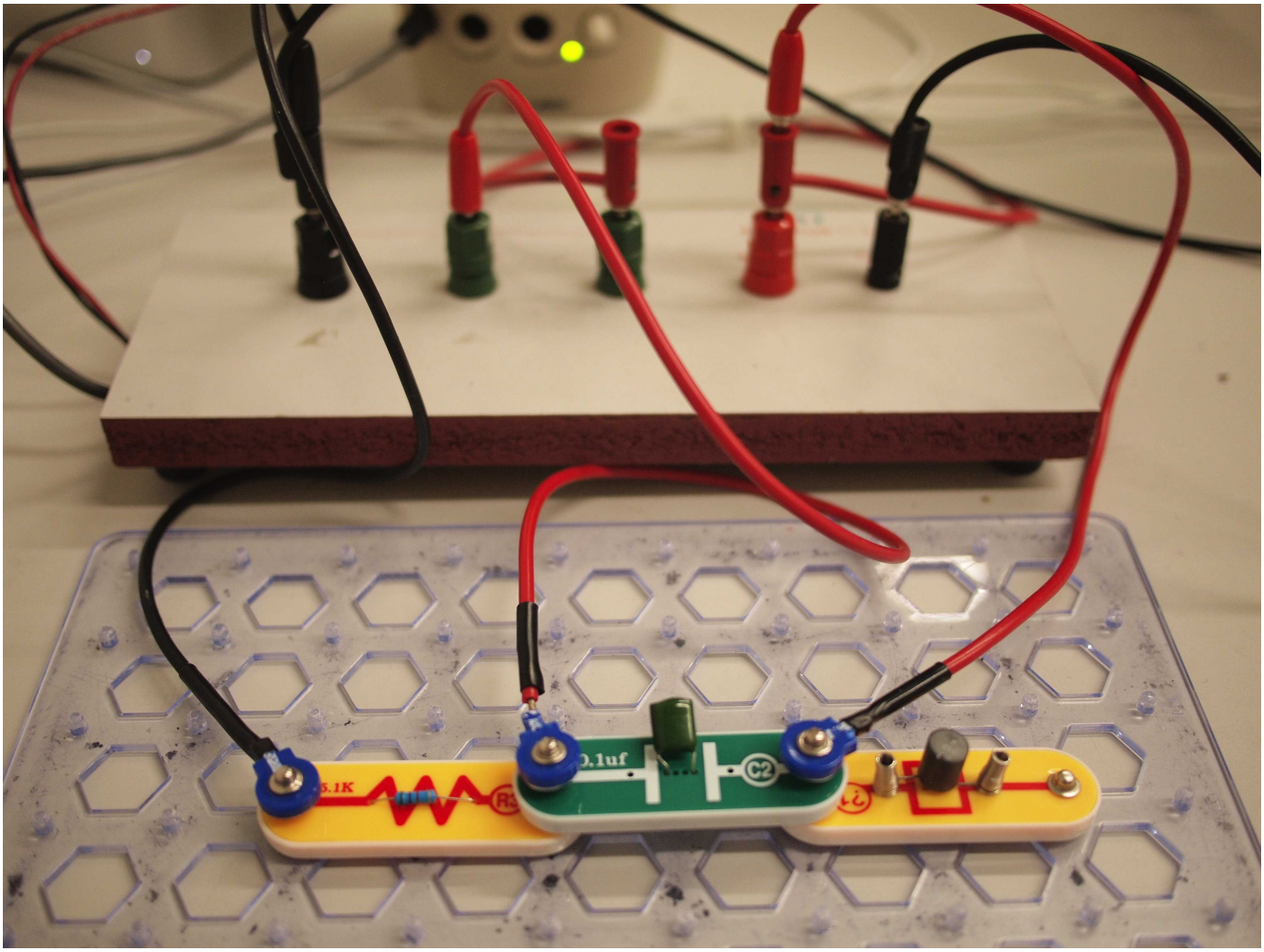


Figure 1

In between the SnapCircuits board and the PC speakers is the intermediate connection panel (rectangular patch panel with five jacks on top, two cables in the rear). See the photo above. This panel distributes the signal between the PC and the circuit. Check to see that the wires in the rear of the panel are connected to the speakers as follows:

- the Read side (Microphone icon) should be plugged into the Microphone jack on the speakers

- the Drive side (Headphones icon) should be plugged into the Headphones jack on the speakers. **Note that you will keep this plugged in for Parts A & B of this lab, but you must unplug it for Part C (AM radio circuit)**.

- there are permanent two permanent "jumper" cables; one connects Read Ground to Drive Ground (to protect from possible short circuits in the Mac's sound card due to faulty connections), the other connects Read Right to Drive Signal (to be able to see the blue trace of the driving wave simultaneously with the red trace of the red response wave). **Please do not remove these two cables.**

Also check that the speakers are on, with the volume roughly in the middle position.

Examine the photo below.. The connection points on the SnapCircuit board have been labeled, from left to right – G, 1, 2, 3. Use this as a guide for future connections:

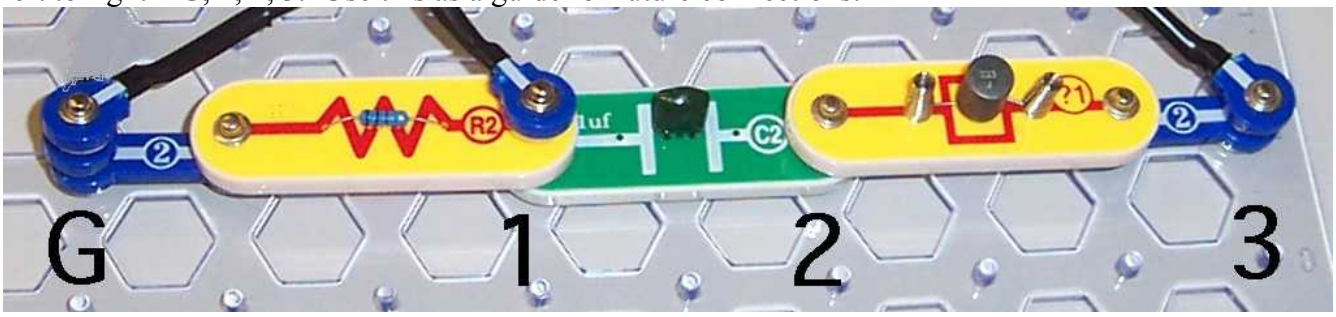


Figure 2

Ignore the R, L, C values for now; above is a sample photo. There are three wires from the patch panel. The black wire always remains plugged in to connection G; Left Read (LR) always stays on connection 1 The remaining Drive Signal (DS) wire is either placed on connection 2 (for an RC circuit) or connection 3 (for an RLC circuit). Read signals are between the LR position and G.

Part A - RC Circuit, driving with square wave (R=5.1 kOhms, C = 0.1 microfarad)

For RC connection, DS goes to connection 2, leaving the inductor with no connection on its right terminal. **Use the 5.1k Ohm resistor between connections G and 1**. See Figure 1.

1. In the Lab Apps folder on your desktop, locate and launch FFTScope application. On the left, go to Signal Generator and select Square waveform. At the bottom of the Signal Generator section, type in 200 Hz. This is equivalent to letting a battery charge the circuit and then disconnecting the battery one hundred times a second. Select the Oscilloscope Dual Channels and observe the resulting trace.

2. Click and drag to zoom in on a few waveforms; use the Autoscale button to fit the peak-to-peak trace in the window. If you zoomed in too much, you can always double-click on the window to regain the full time scale. The the red trace represents the response of the RC circuit. Look for exponential decay (both positive and negative, since we are reversing the pulse with each cycle).

3. Click and drag again, this time to isolate one decay curve. Try to select the smooth part of the curve, without any significant sharp peaks.

4. Go to Edit-->Copy. Open Time Constant Analysis.ga3, which is a Logger Pro file in the same folder as this write-up. Click on the first cell in the first column ("t-scope"), and select Edit-->Paste. The decay curve should appear on the graph window, with the time axis reset to zero at the origin.

5. Go to Analyze-->Curve Fit and try an exponential fit. Calculate the decay constant from the fit coefficients, and the value of C based on the known resistance. **Remember that the graph plots the Time in ms (milliseconds).** Do not print out a graph.

Part B - RLC Circuit, driving with square wave (R=100 ohms, C= 0.1 microfarad, L=33 millihenries)

See Figure 2. For RLC connection, DS goes to connection 3. Change the resistor to one of lower value – 100 ohms; anything higher and you will not see even one oscillation – this is called overdamping. Note this value down in your hand-in sheet.

1. Again select Square waves, 200 Hz, to drive the circuit and observe the response waveform within each cycle. Zoom in on one decay cycle to examine the envelope (exponential decay of peaks) and waveforms within. Zoom in again, this time to show only the first two waveforms. Autoscale. Measure the period between these two by positioning the cursor at the peaks and reading off the corresponding value in the lower left-hand corner of the FFTScope window and calculate ω_0 . **Remember that the graph plots the Time in ms (milliseconds).** Show calculation in hand-in sheet. Indicate there how closely theoretical frequency (from labeled values of L and C) agrees with experimental frequency (as measured from period).

2. Thus far you have been using FFTScope to observe Amplitude vs. Time of the circuit response. You will now observe the response in Amplitude vs. Frequency space. Click on the "fft complex left/right ratio" button (bottom button) to observe the FFT (Fast Fourier Transform – this is a mathematical method to find the characteristic, or natural frequencies of an electrical or mechanical system) spectrum. Select "FFT averaging on" on the lower-right and watch the curve rise. Autoscale. The peak of the curve should correspond to the frequency you calculated/measured above (you can find the frequency by positioning your cursor at the peak and reading the the value from the bottom of the window). Is this in fact the case? Answer in hand-in sheet.

Alternatively, you could select "fft on left channel" and ignore the harmonics (frequency multiples) of 200 Hz, or use "white noise" in Signal Generator.

3. If resources allow (if there is enough equipment), add a second capacitor in series with the first one and observe what happens to the FFT peak you obtain above. Explain in the hand-in sheet why this changes.

4. If resources allow (if there is enough equipment), remove the second capacitor and add a second inductor in series with the first one and observe what happens to the FFT peak you obtain above. Explain in the hand-in sheet why this changes.

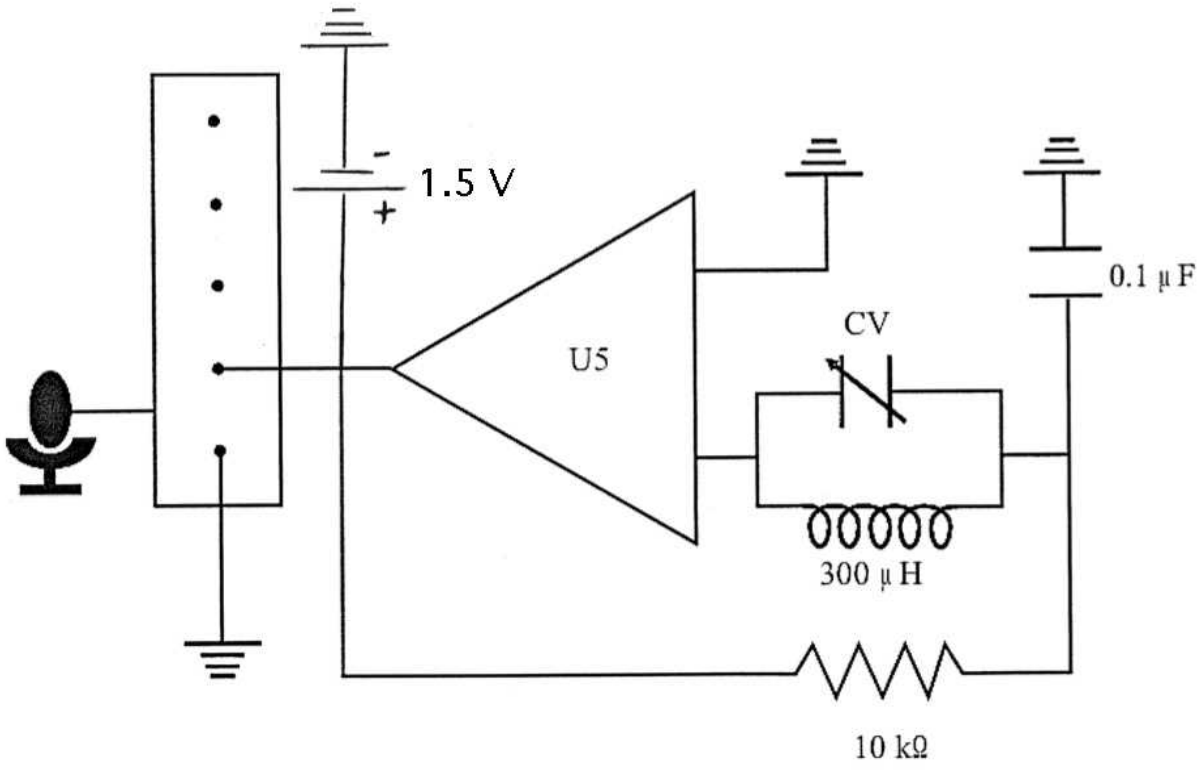
Part C – Building An AM Radio (R=10 kOhms, L=300 microhenries, C (variable)=30-230 picofarads)

IMPORTANT: Make sure that nothing is plugged into the Headphones jack on the speakers.

0. **QUIT FFTScope (very important!).** Unplug the cable from the speakers headphone jack. Disassemble the RLC circuit you built in the previous section.

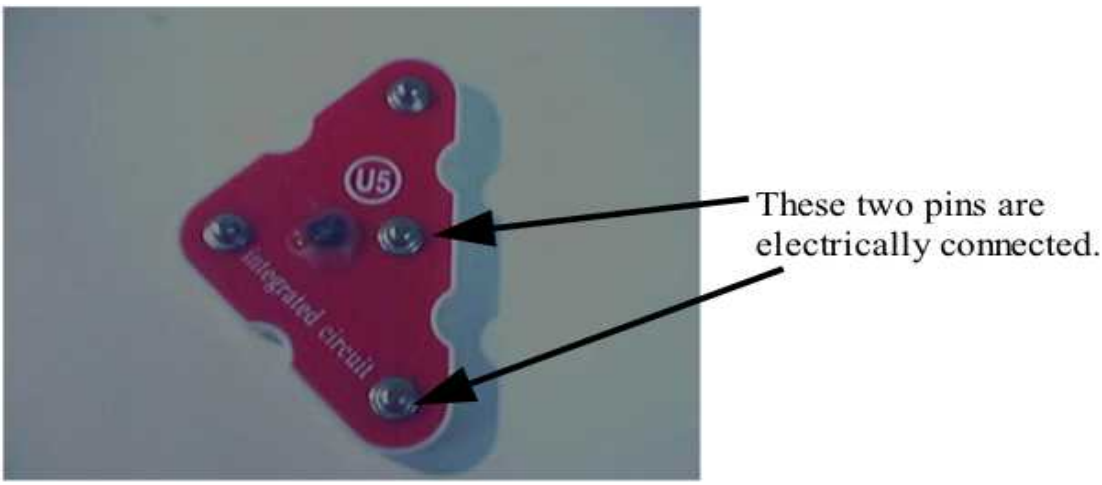
1. Launch the "Line-In" application, which is found in the "Lap Apps" folder on your desktop. There is no need to adjust the slider as the function is automatic.

2. Now that you know how to put together an RLC circuit, you can start assembling an AM radio. You will use the following schematic:



Note that in the schematic above, you will no longer be using the inductor that you used in Parts A and B; the antenna coil doubles as the inductor (L = 300 uH). In the schematic, you will see multiple connections to ground. **Remember that you do not need multiple connections to ground, since a single pathway from two connected points to ground will suffice. This is known as *common ground.* It is therefore not necessary to use more than the three banana-to-button cables provided.** If you need additional guidance on how to assemble the AM radio circuit, you should look at the picture on the first page of the write-up to see how the connections are made. In addition, you will have a different set of blue electrical connectors to assemble the circuit. The single blue connector does not connect anything but rather serves to raise one component to the level (height) of the other components on the circuit board. It should also be noted that two of the pins of the integrated circuit

are electrically connected as shown in the figure below. Finally, you will also need to insert a SnapCircuits battery element (containing a 1.5V battery) into the circuit.



2. You will tune by turning the knob on the variable capacitor (CV) and adjust the volume from the speaker volume knob; the circuit gets its power from the speakers. Turn up the volume so you hear some static.

3. One of the very first wireless transmissions (and the first confirmation of the existence of EM waves) was made in when Heinrich Hertz produced and detected waves using a spark-gap circuit (Maxwell had predicted the existence of the waves in 1862). In an effort to duplicate this, use the battery on your lab table and briefly connect the top and bottom terminals using any of the circuit cables. You should see a little spark – you have just produced an EM pulse. If your radio is properly assembled, you should hear something happen – write down what you witness in your hand-in sheet.

4. You will need to touch both the A1 antenna with one hand and the ring stand (sticking upward from your lab table) with your other hand to get good reception. The ring stand is connected to a long external antenna that is mounted outside the building. **IF YOU ARE STILL HAVING TROUBLE PICKING UP A STATION, TOUCH THE METAL BACK OF THE CV CIRCUIT ELEMENT.** Pick up the strongest station and identify it (by its call letters, frequency, and location as announced on the station).

5. Based on the values of C (variable) and L, determine the range of frequencies this AM Radio circuit should be able to pick up. Write in hand-in sheet.

Radio Frequency Experiment by BH1RBG

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  - RF Practice: better to know
  - Run into Wide-Band Buffer/Amplifiers
  - Super Regen: Make it work
- Homebrew Craft
  - Air Coil 4.5 Turns example
  - experimental board

RF Homebrew Instrument >

SWR: the Good HF QRP SWR

@8/27 2015

An SWR meter is mandatory for any Ham, i think. surfing on WWW, there are many SWR builder and many SWR bridge presented. classify SWR might base on different aspect of the SWR.

for working frequency range, some only work on HF, some only function well on V/UHF band, there are some type SWR working in a really wind band, but limited on other factor, ie, resistance bridge SWR working on a wide range band but it's not a In-line SWR, after tuning the Antenna, you need remove the SWR or lift the switch to switch out the SWR.

some SWR don't need to remove from transmission line, this is in-line type SWR, most of this SWR is base on some directional coupler method.
An popular classify is based on what kind of bridge it use, ie, the resistance bridge, Tandem bridge SWR, Bruene bridge SWR, etc.

some directional bridge might be good performance but building them is challenge, like sloted line coupler(<<Radio handbook>>) or the left picture * (from http://ve6atv.sbszoo.com/).

Fuse based dead bug
RF Calculators
Heterodyne tracking calculator
RF Experiment
AMP: Simple RF Amplifer
Antenna: JFET active attenna
Audio: 2 stages Transformer Audio PA
Audio: Discrete Power Amplifer
Audio: low distortion wein bridge
Audio: Pre-amplifer 2011
Audio: Push Pull PA
Audio: Simple power amplifier
Audio: wein sine bridge
Bias: favorite BJT/JFET bias guide
CXO: CXO/overtone for TX
CXO: Low distortion oscillator
CXO: Tune 5th Butler Overtone VHF Oscillator
Fail: CB Negistor-not work
IF: BJT 2 Stage with AGC
LiPo: Simple charger
Miller negative resistance Oscillator
Mixer: JFET active mixer
Oscillator amplitude stabilization
Ramp: linearity ramp genarator
Ramp: Versatile ramp generator
SA: What is SA (SA demo prj)
Supply: dual Li-Po 7.2V-8.2V
Sweep: Build new topology signal source
Sweep: simple Hartley Sweeper
VCO: Franklin 80Mhz-180Mhz
VCO: AM Hartley LO
VCO: CB colpitts 270Mhz-500Mhz
VCO: Improved Series E VCO
VCO: linearity factor
VCO: Negative resistance VCO
VCO: Negative VCO Linearity
VCO: Seiler 80Mhz-300Mhz
VCO: Ultra Negtive 100kHz-100Mhz
VCO: Vackar 30Mhz-240Mhz
VFO: ultra-audion LF to VHF
VFO: AM band Oscillator
VFO: hybrid feedback oscillator
VFO: Several Dipper Ocillators
VFO:New topology of Series-E oscillator
RF Ham Radio
10M:28.6Mhz FM transmiter
27Mhz: AM RX/TX Experiment
AM: AM band transmiter by Techlib
Antenna: Your first Antenna

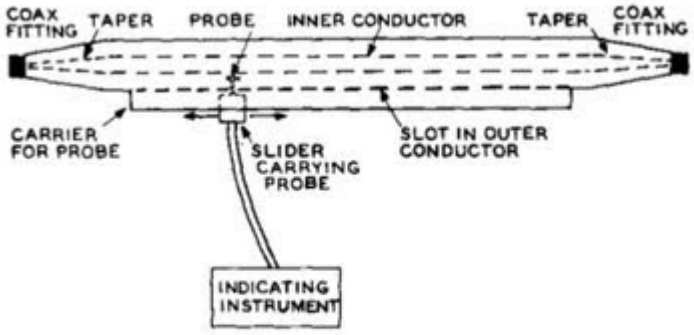
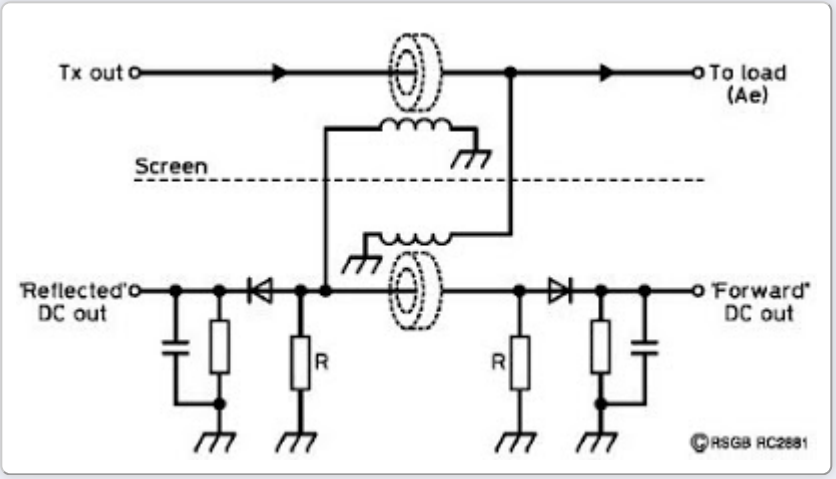


Figure 12
DIAGRAMMATIC REPRESENTATION OF A SLOTTED LINE



Selecting an Bridge

inline SWR bridge have 2 popular choice, one is Tandem bridge(RSGB handbook).

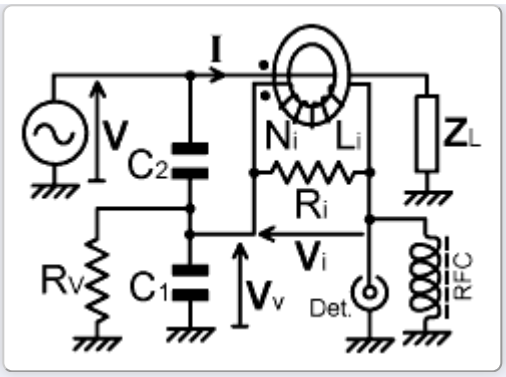


Bruene bridge (sensitivity change with frequency) (http://www.g3ynh.info/)

DC: Improvise Better Polyakov
DC: Polyakov The First DC receiver
Experience Crystal Set up to Superhet
FM Synchrodyne
Heterodyne: BJT AM receiver
Heterodyne: Build A Traditional Radio
HF: 0.5W Linear push pull PA
Regen: Aamazing Regen Receiver
Regen: High Performance Rig
Rflex: with voltage doubler detector
SuperRegen: AirCraft band receiver
TRF : the origin of Receiver
TRF: infinity JFET 0V2
RF Homebrew Instrument
3D printer make RF fun and cool
Attenuator: 50ohm/81dB 1dB step
Attenuator: 600ohm 1dB Step
Attenuator: Serebriakova 13-40dB
Audio: low THD two tone generator
BAT:servo constant current load
Bias: JFET Bias tool box
Bridge: RLB VHF
Couter: EP frequncy counter
Crystal: checker
LiPo:Dummy Blance charger
NICD: Dummy Discharger
Power Meter: AD8307
Power Meter: Calibrator
SA: PC sound card oscope
Sawtooth: Ramp signal source
Signal: Build The Log Detector Sweeper
Signal: Improve The Log Detector Sweeper
Signal: Prototype of Log Detector Sweeper
Sweep: boostrap sweeper
Sweep: manual sweep signal source
SWR: the Good HF QRP SWR
Sitemap

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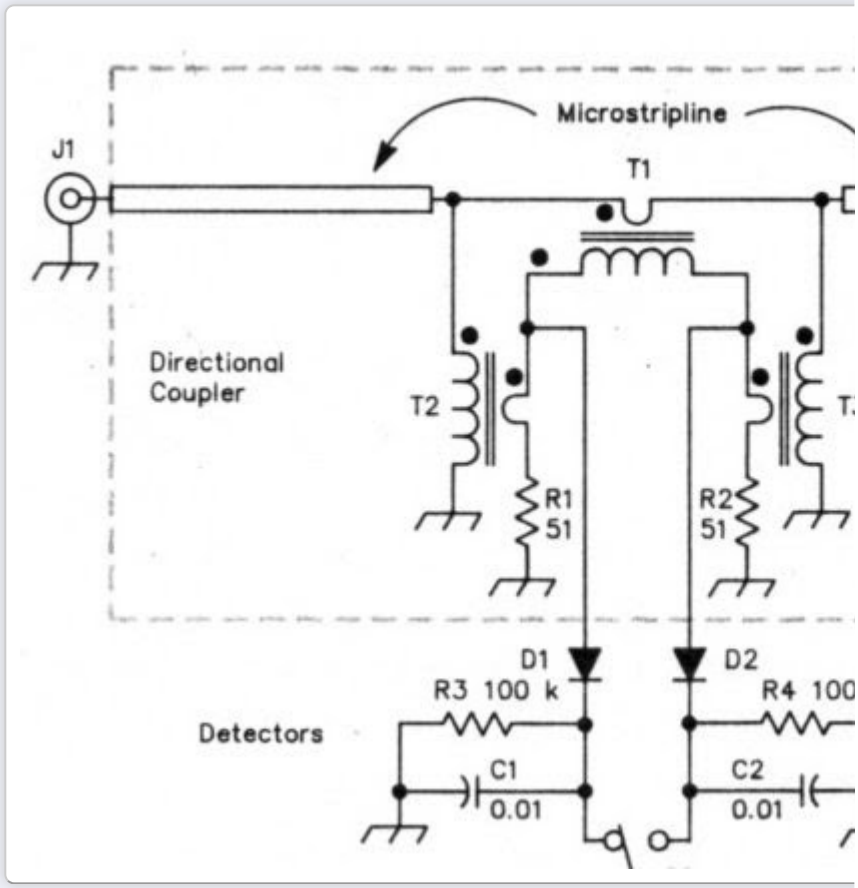
heyongli@gmail.com

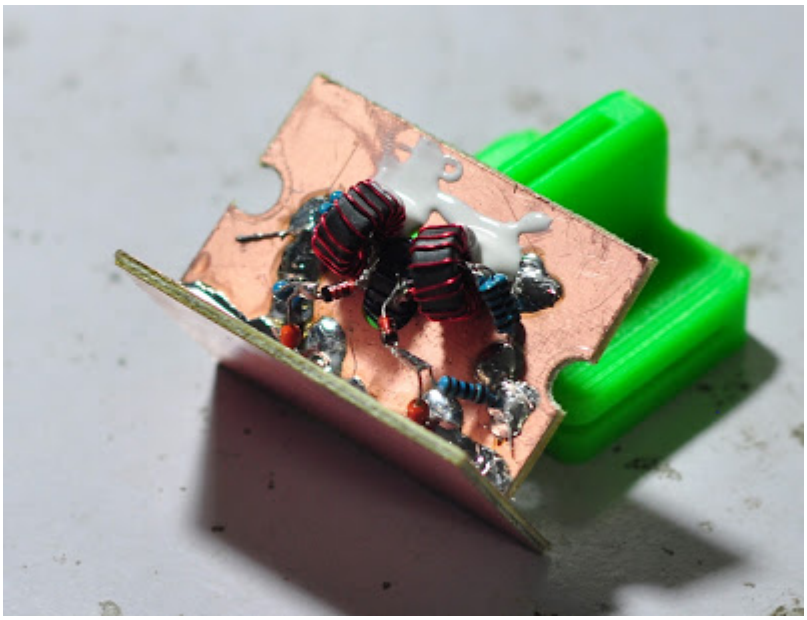


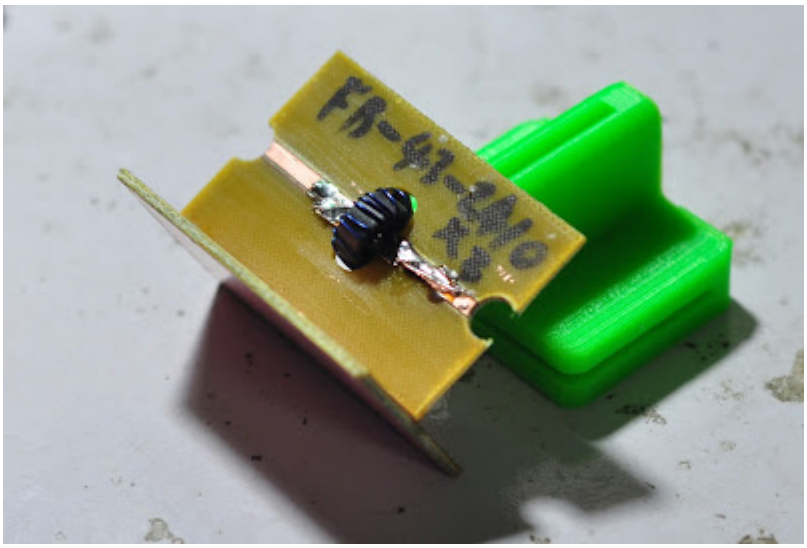
A transformer voltage sample Bruene from QRP article by W7EL

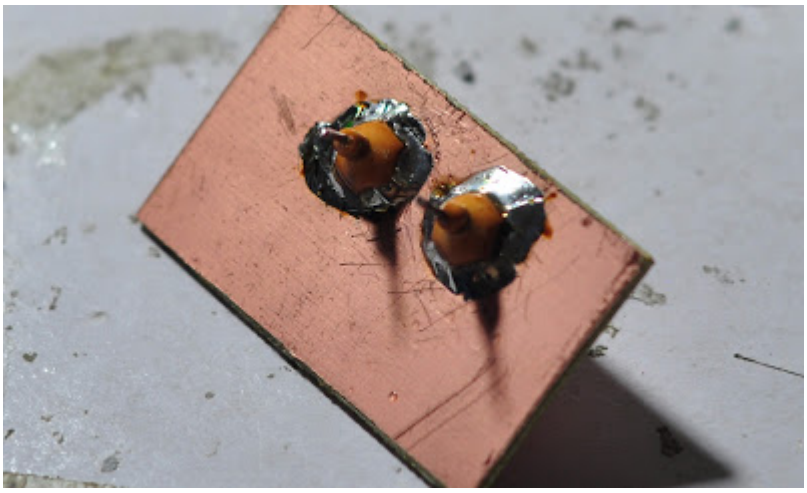
http://www.qsl.net/kl7jef/QRP%20Directional%20Wattmeter.

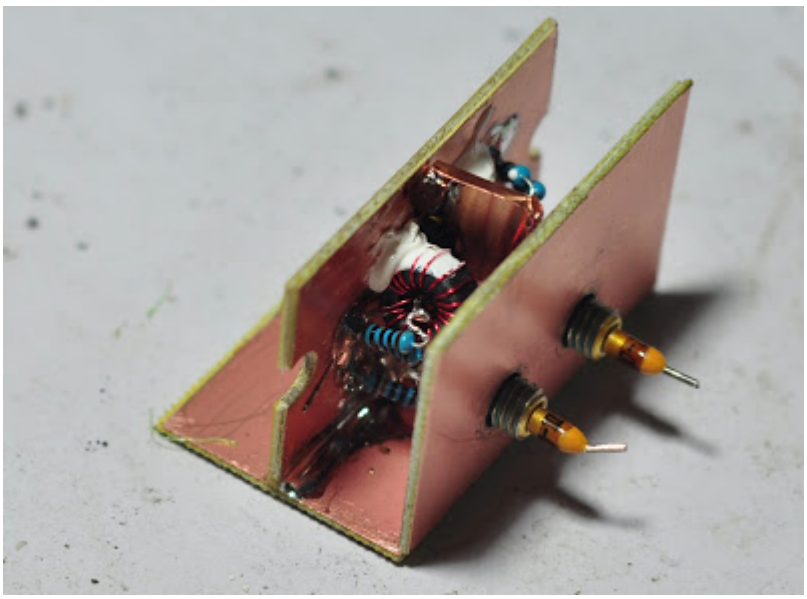
this is actually design for a Power meter, i use it as a QRP SWR.
D1, D2: 1N60.
T1, T2, T3: 20T on FT-37-43 (no available FT-37-72), secondary of T2, T3, primary T1 is one turn (use the component lead).

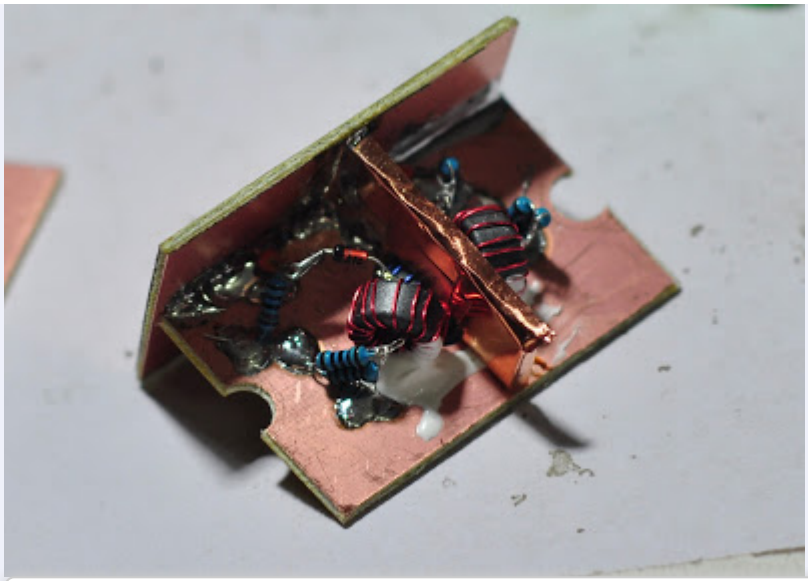

Microstripline
J1
T1
Directional
Coupler
T2
R1
51
R2
51
D1
D2
R3 100 k
R4 100
Detectors
C1
0.01
C2
0.01







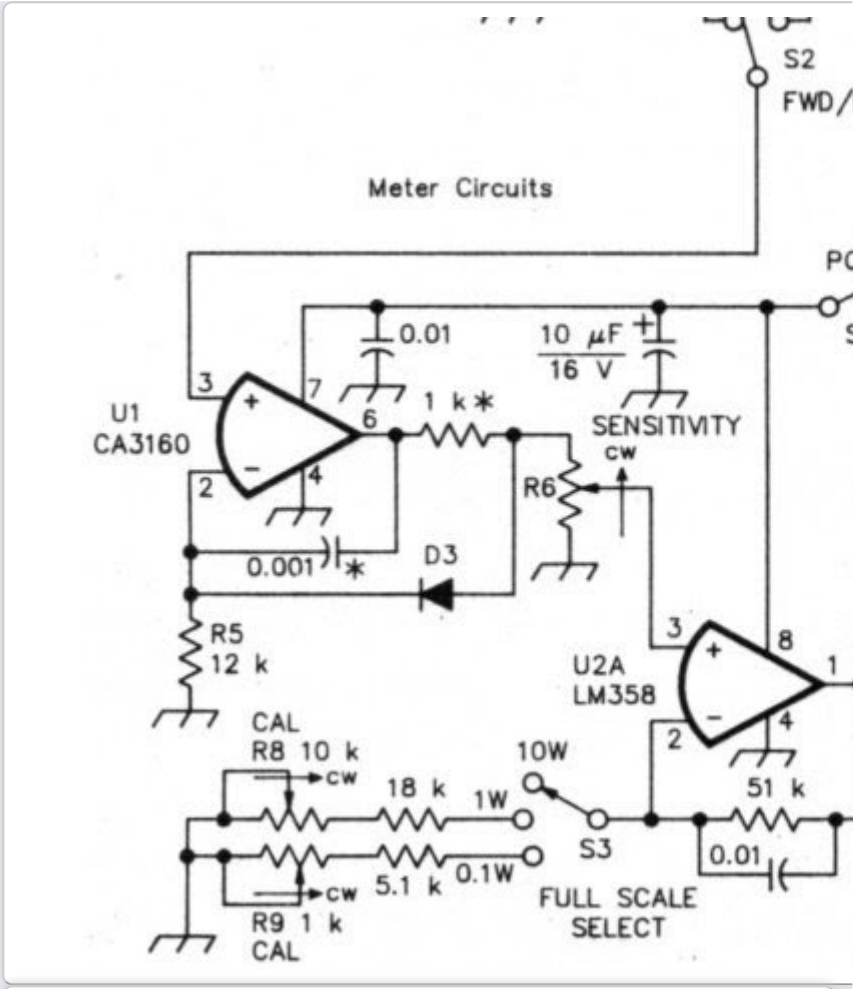


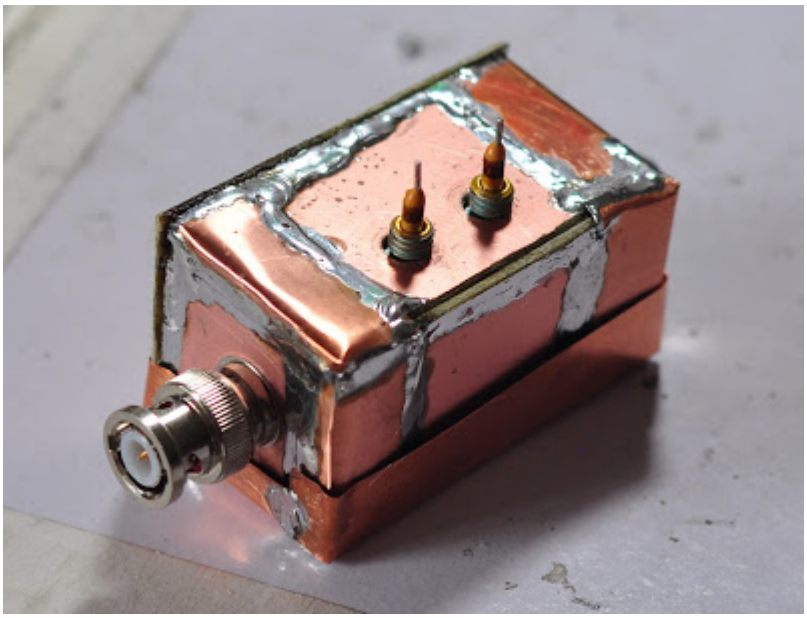




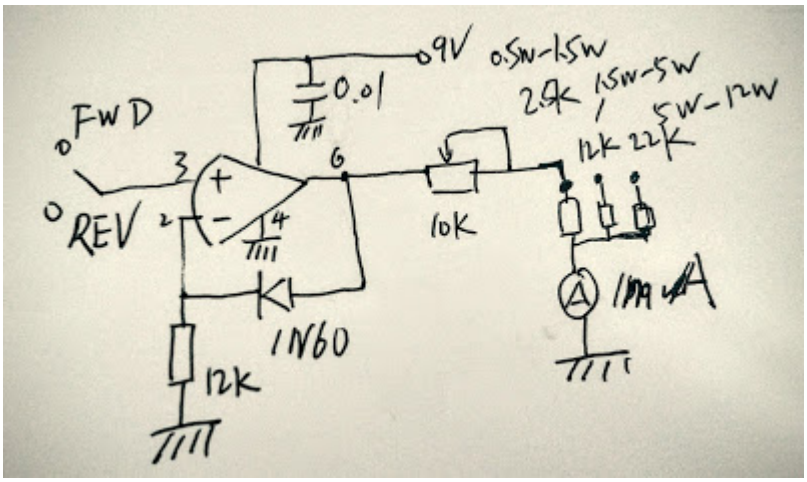
Detector and compensate

see the schematic below. i don't use the U2A, just use one CA3140 as compensate.

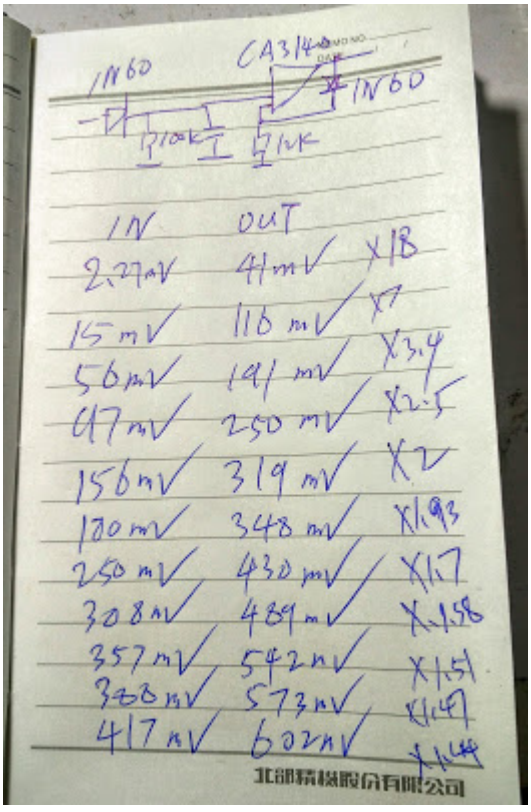




and not use the 1k output resistor and the 0.001 uF capacitor i see no unstable problem:



how the compensate works? the 1N60 is almost a resistor changed depending output, before it's driven to fully conduct. here is a IN/OUT testing result, the Input read on oscilloscope(pp), output is DC voltage reading from Multimeter.



Result, a good HF up to 6 meter SWR

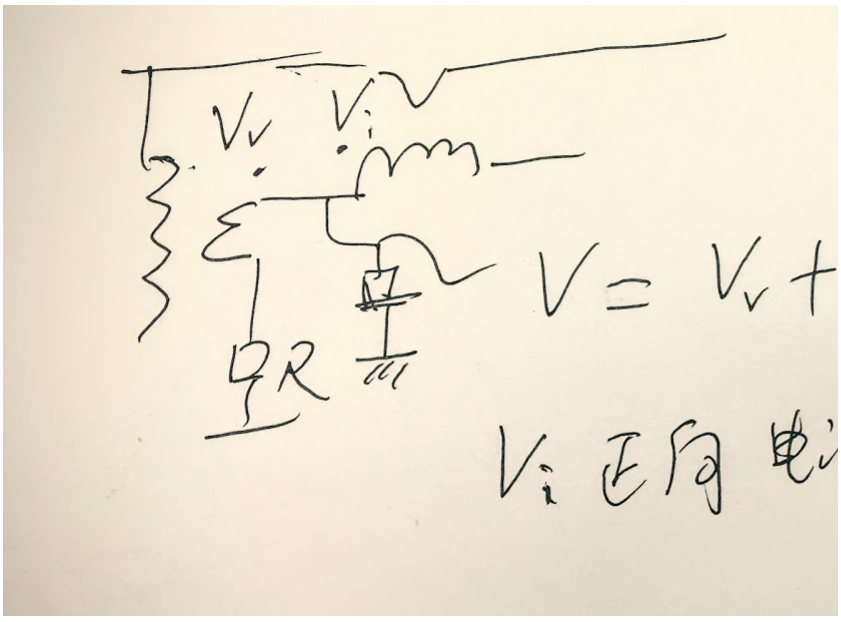
* it's works well from at least 3Mhz to 30Mhz, get well Null while connect to dummy load.
* it's also works for 6 meter, ie, the 50 Mhz. still get well Null.
* it's can not get null result at VHF 2 meter band.

how to use it

FWD, adjust sensitive let it get full scale.
then use REV, you got the SWR reading.

how directional coupler works

basically it's how we different the power transfer direction. In a transmission line with a matched load, the current in the direction from source to load peaks 90° than the voltage. If power flow in the other direction, this relationship is reversed. so the meter get a +-90 degree current sample add to a same phase voltage separately, we get the 2 direction's power.



one confuse thing is while i calculate the Vi + Vv, do i need to consider another side of the T1? i always make concept there mixed together, because current flowing through

both T2 and T3's secondary, so i wondering the FWD position's output will impact in some way by the T3's secondary. it does affect the total current, but actually, it's nothing to worry about to get the correct Vi+Vv. just considering the T1's each output terminal as a AC voltage source.

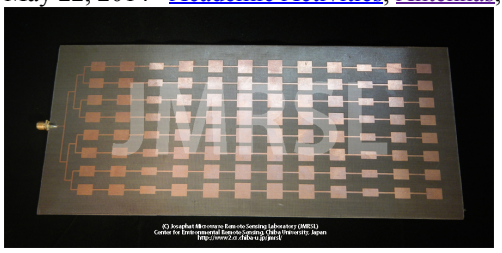
Comments

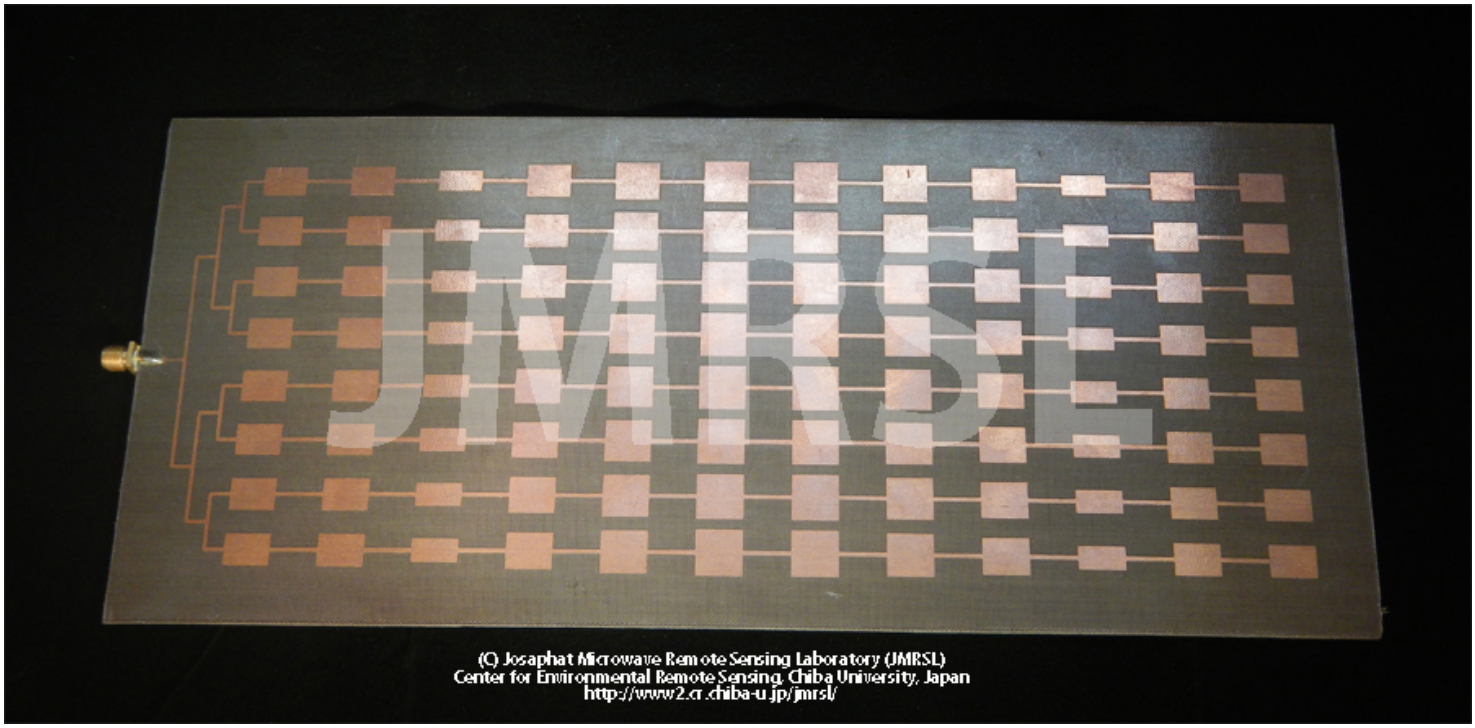
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Weather Radar Antenna

May 22, 2014 Academic Activities, Antennas, Research Activities





Antenna for X band weather radar

Josaphat Laboratory develops some antenna for weather radar, i.e. antenna for X band weather radar.

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- **Trans 7 TV : Prof Josaphat**



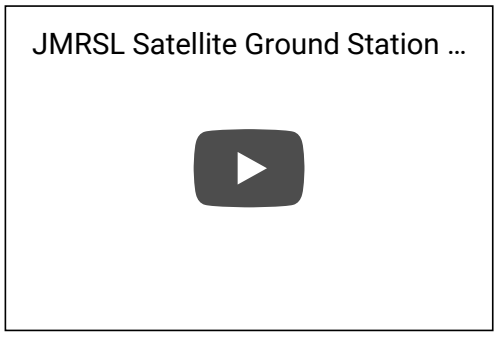
Trans 7 TV : Prof Josaphat on 20 October 2015

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- **JMRSL Satellite Ground Station**



Josaphat Laboratory Satellite Ground Station

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- **JMRSL UAV JX-1 Flight Mission**

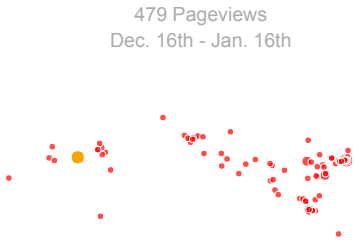


JMRSL UAV JX-1 Flight Mission

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Home

Radio Coils





Reaction Radio Coil 1000-4000 kHz 40 µH coil with tickler and aerial winding. Base pin numbering is the same as the Denco . Larger View

P/N
20-151
£ 15.00



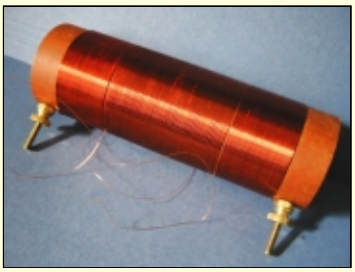
Reaction Radio Coil MW Range 160 µH coil with tickler and aerial winding. Base pin numbering is the same as the Denco Green range. Larger View

P/N
20-152
£ 15.00



PAXOLIN COIL FORMER 1.5 inch Diameter x 2 inch Long (37.5mm x 50mm) Larger View

P/N
15-001
£2.00



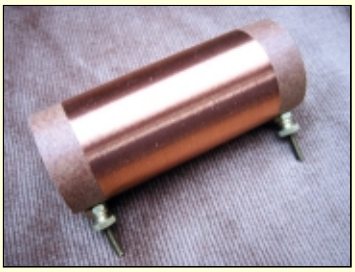
MW MYSTERY COIL MK1 240 µH Medium wave band mystery coil. Mk1 Larger View

P/N
20-001
£18.00



MW DUAL DIODE COIL MK1 Two Separate Medium wave windings of 240uH plus aerial coupler coil in Centre. Larger View

P/N
20-002
£22.00



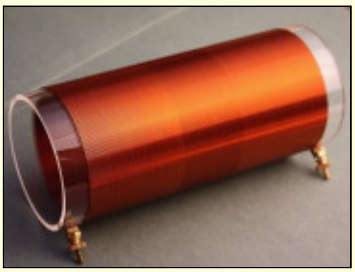
2.5 mH CHOKE 2.5 mH RFC, air core. Larger View

P/N
20-003
£12.00



VARIOMETER FOR VALVE RADIOS Just what you need for that one or two valve set. There is a main coil to tune the MW band, an antenna input coil and a rotatable reaction (tickler) coil. Larger View

P/N
20-004
£50.00



LONG WAVE MYSTERY COIL This coil is 1600 uH inductance and measures 7 inches long x 3 inches diameter (175mm x 75mm). I have wound this using my AVO Douglas Winder Machine which produces very precise windings. Larger View

P/N
20-007
£30.00

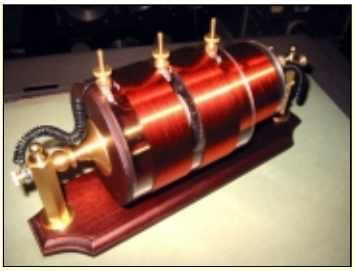


240 µH COILS Medium wave coil, 3 inch diameter and 2 inches long. Solid brass knurled nuts. Larger View

P/N
20-998
£ POA

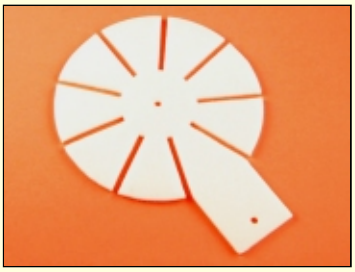
LOOSE COUPLER MK2 Dark stained and polished sycamore

P/N



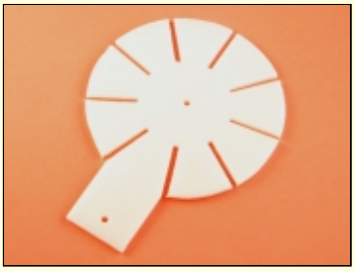
Base Coil about 10 inches in length overall. Inductance 300µ Henries on main coil which is centre tapped. Secondary coil slides into main coil on a brass shaft. It has six tappings and 200µ Henries in total. Larger View

20-999
£ POA



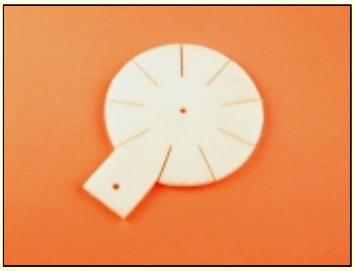
240µH, 4.75 Inch Former This spider coil former is made from low loss HDPE. MW wave detectors can be easily wound using 100/45 or similiar litz wire.

P/N
15-004
£ POA



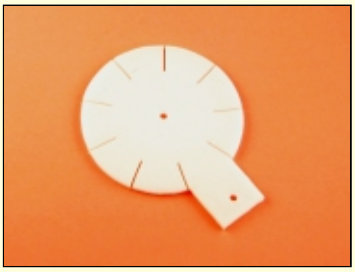
150µH, 4.75 Inch Former This spider coil former is made from low loss HDPE. MW wave antenna tuners can be easily wound using 100/45 or similiar litz wire.

P/N
15-005
£ POA



240µH, 3.50 Inch Former This spider coil former is made from low loss HDPE. MW wave detectors can be easily wound using 40/44 or similiar litz wire.

P/N
15-006
£ POA



150µH, 3.50 Inch Former This spider coil former is made from low loss HDPE. MW wave antenna tuners can be easily wound using 40/44 or similiar litz wire.

P/N
15-007
£ POA



40/44 LITZ WIRE 40 strands of 44 AWG litz wire

P/N
19-001
POA

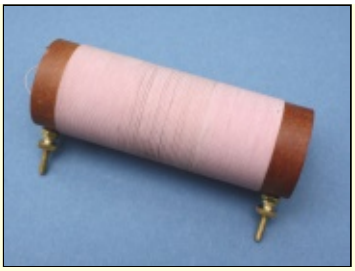


100/45 LITZ WIRE 100 strands of 45 AWG litz wire.

P/N
19-002
£ POA

MEDIUM WAVE LITZ WIRE MYSTERY COIL 250µH. I

P/N



wound this coil using best American (Kerrigan -Lewis) litz wire 100/45 type. This coil has a higher Q (magnification factor) than magnet wire coils and will make a more sensitive and selective radio. Litz wire was the most favored by the vintage crystal radio builders of the 1920's and is still the best. Today you cannot get a more authentic looking coils than this particular type.
Larger View

20-008
£20.00



LITZ WIRE LONG WAVE COIL 2000µH This *Mystery type coil* is 7 inches long and 3 inches diameter fitted with solid brass binding posts. There is a very tight close wound coupling coil section terninated at two solder tags on end of coil. I wound this on my Avo Douglas hand operated coil winding machine which produces a very precise and even winding.
Larger View

P/N
20-010
£25.00



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Brand New

$17.99

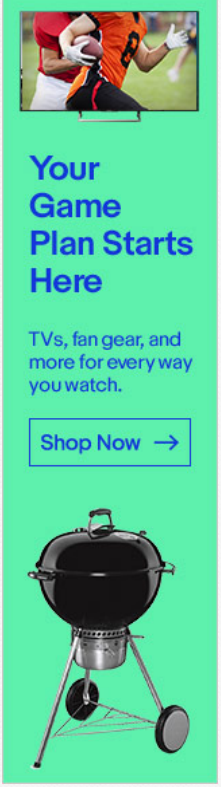
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Free Shipping

5 Watching

5.8GHz Triple Feed Circular Polarized Patch FPV Antenna

Brand New





$16.99
Buy It Now
Free Shipping



Aomway ANT018 Triple Feed Patch+2pcs CloverLeaf Antenna f FATSHARK LaForge TrueD
Brand New

$19.99
Buy It Now
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8 Watching



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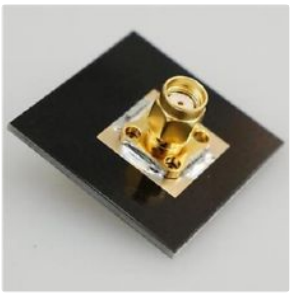
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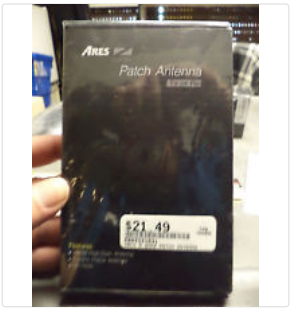
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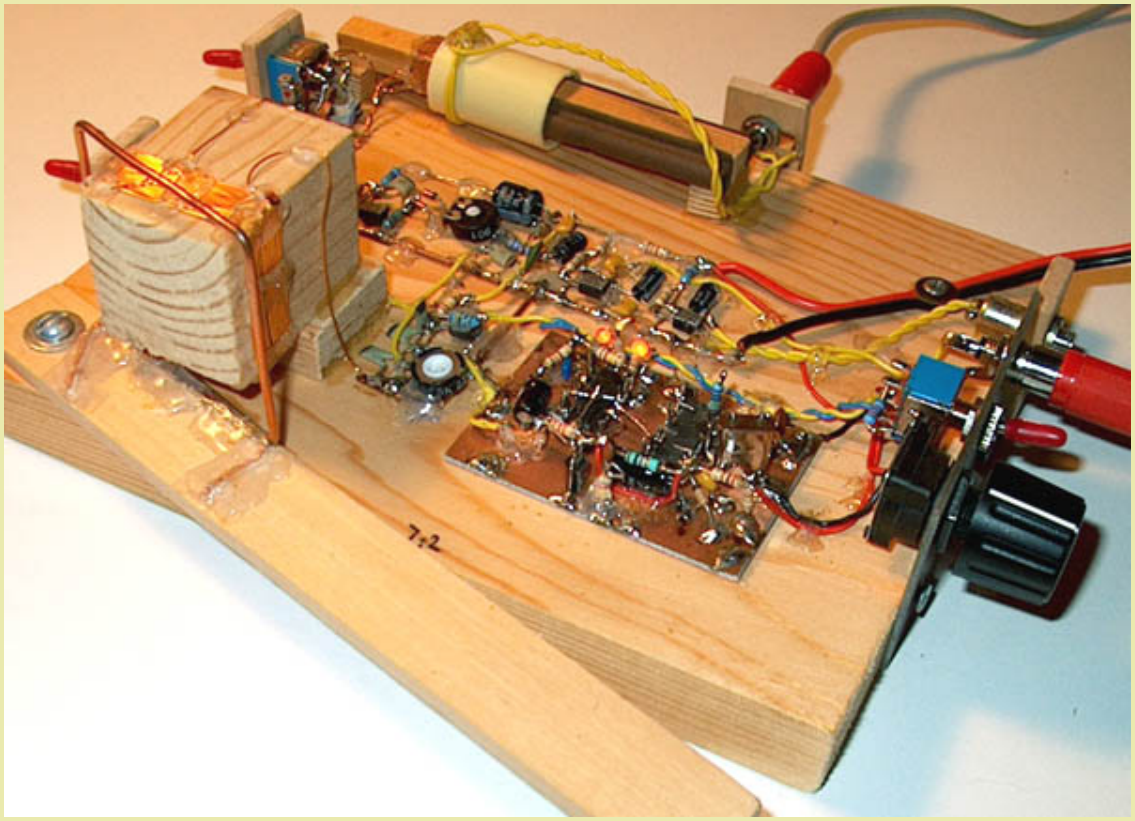
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MODIFIED FREQUENCY STABILIZER FOR PSK31 RECEPTION WITH THE SIMPLE RECEIVER

(2008)

KLIK HIER VOOR DE NEDERLANDSE VERSIE



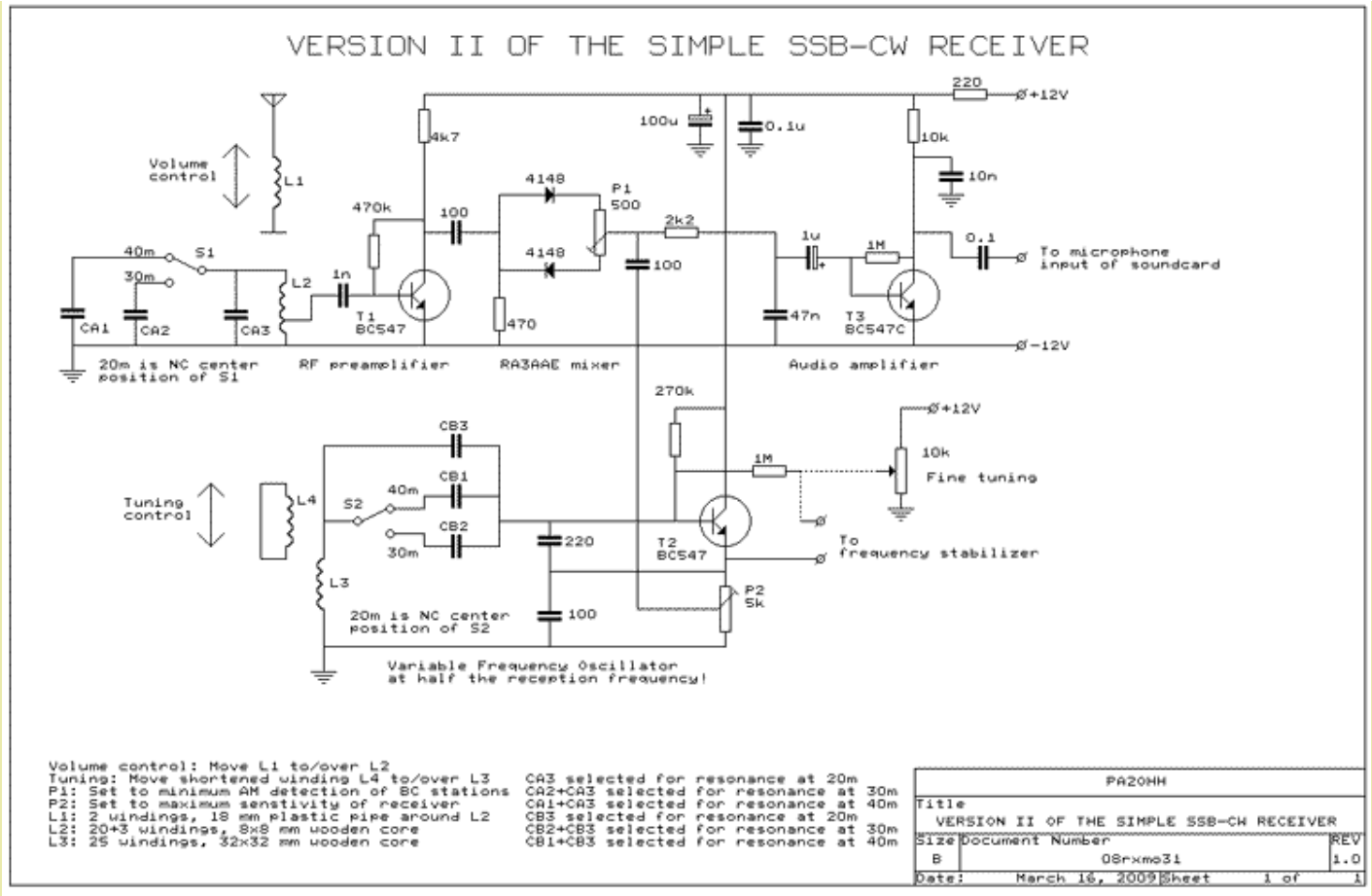
Simple SSB-CW receiver with a modified frequency stabilizer for PSK31 reception and fine tuning.

The simple receiver that has to be stabilized

For the tuning mechanism, no variable capacitor is used but a wooden stick with a shortened winding of copper wire, moving to the VFO coil! The volume control is an antenna coil on a plastic tube that can be moved to- and over the input coil.

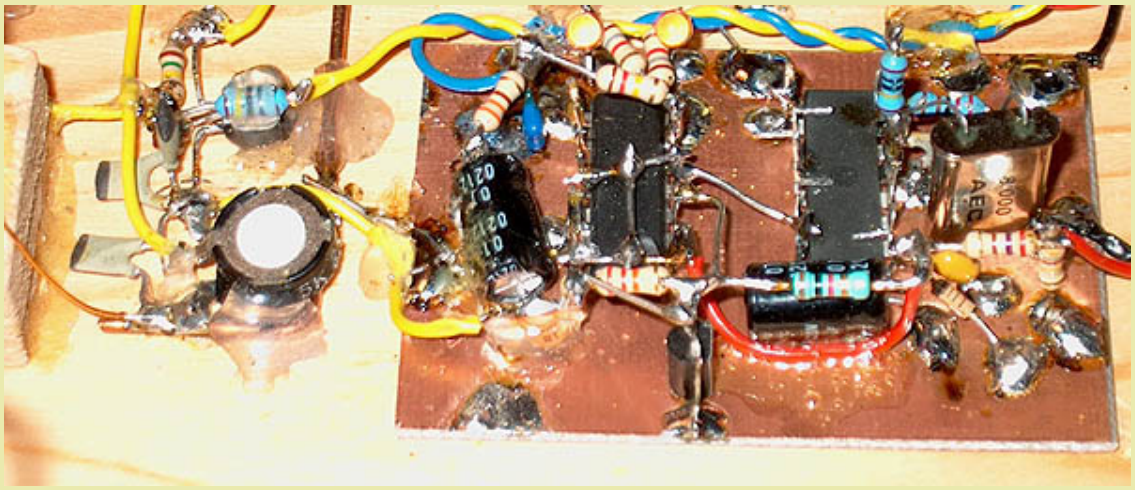
A complete description of the original receiver can be found by clicking on the next link:

SIMPLE RECEIVER FOR 40 AND 20 METER



The new version of the receiver with fine tuning, 30 meter band and a connection for the soundcard of the PC.
big diagram

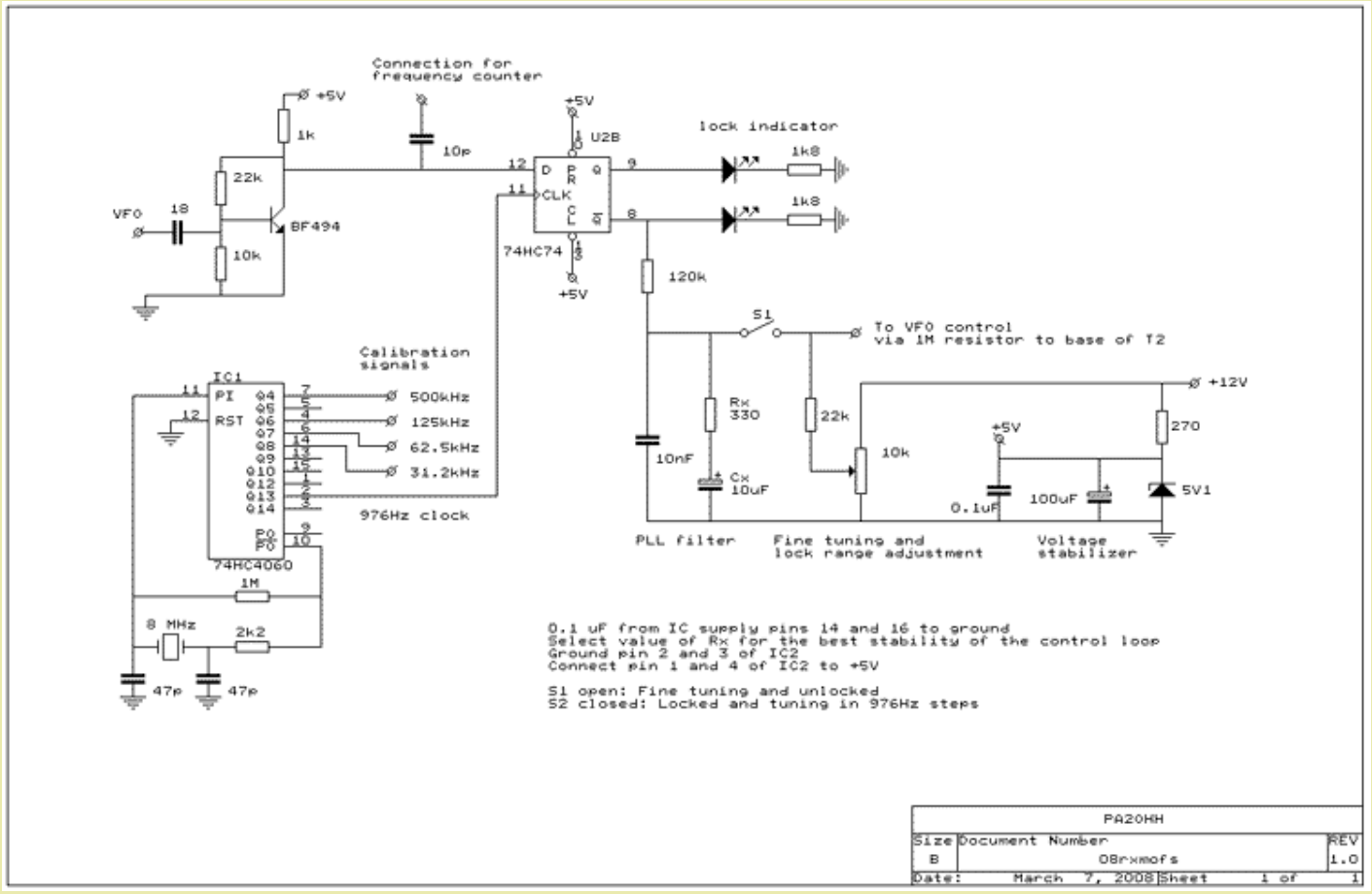
Modified frequency stabilizer for PSK31 reception
The VFO is not stable enough for PSK31 reception. That is very understandable, it is a simple and open, unscreened construction. That is why we have to stabilize the VFO with a frequency stabilizer. That was not possible with a normal Huff & Puff circuit, but it was possible with a modified version.



Modified simple frequency stabilizer and VFO.

It looks like a very normal Huff & Puff frequency stabilizer, but it is a special version. Usually, we use a clocksignal of 10 to 50 Hz in a Huff & Puff stabilizer, so that the VFO signal locks in the same small frequency steps. But the VFO of this simple receiver was not stable enough for such small frequency steps. The frequency varied within 1 or 2 seconds already 10 to 20 Hz. To make it possible to use a Huff & Puff circuit, a much higher clock frequency of approximately 976 Hz is used. Controlling the frequency goes much faster and the VFO can be locked every 976 Hz (8 MHz / 8192). These 976 Hz steps are too large for SSB and CW, but not for PSK31 reception. As the VFO frequency is equal to half

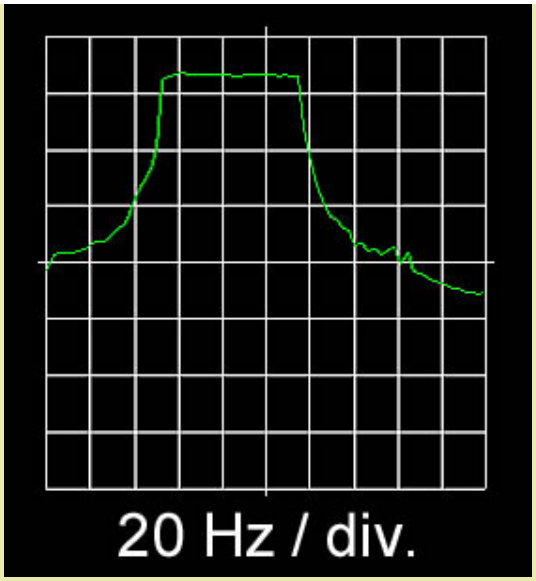
the reception frequency, the receiver is tuneable in steps of 2 x 976 Hz = 1952 Hz! These large steps are not a problem at all for PSK31 reception with the PC.



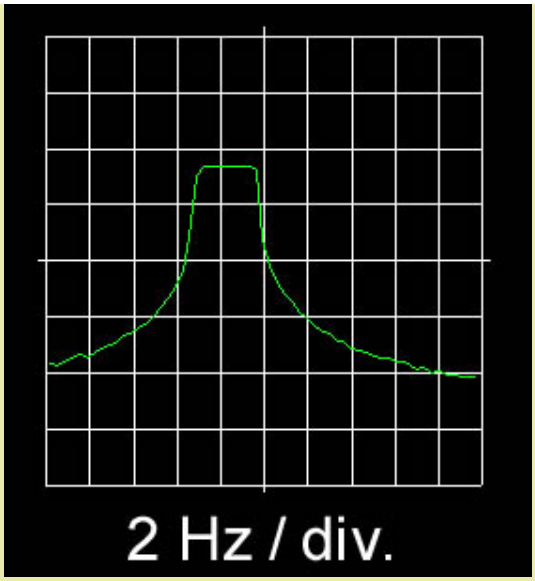
The frequency stabilizer with fine tuning.
big diagram

The modified frequency stabilizer
Much information about Huff & Puff frequency stabilizers can be found on the great site of Hans Summers (search for "Hans Summers" or "G0UPL" to find his site). Nowadays, there are improved versions of the by PA0KSB invented circuit. Here, an older version is used, partly because I had the parts available, but also because it is possible to use this version as a frequency calibrator.

The working principle of this stabilizer is very simple:
In fact it is not a frequency stabilizer but a phase stabilizer. The D-input of a D-flipflop is connected to the VFO signal. The clock input is connected to the clock signal of 976 Hz. On the rising edge of the clock signal, the output is set to the value of the D-input. So a "1" when the clockpulse goes high at the positive part of the sine of the VFO signal, a "0" when the clockpulse goes high during the negative part of the sine of the VFO signal. The output of the D-flipflop controls the VFO frequency via a kind of PLL loop filter.



Reception of the 10 MHz calibration signal without stabilizer during two minutes. Drift already 60 Hz!



Reception of the 10 MHz calibration signal with stabilizer during half an hour. Drift only 2 to 3 Hz!

Without frequency stabilizer, the receiver drifted approximately 60 Hz during two minutes, sometimes already 10 to 20 Hz during a few seconds. With frequency stabilizer, the drift during half an hour was only 2 to 3 Hz at 10 MHz! It was very simple to measure the drift. The receiver was tuned to the 10 MHz signal of my simple frequency standard and the frequency of the LF output signal of the receiver was measured with the soundcard of the PC and an audio spectrum analyzer program.

The loop filter

The frequency control is very simple, it has two settings: Full speed upwards or full speed downwards. So a loop filter is required to slow down and damp this extreme frequency control. Choose the values of Rx and Cx so that the control is stable and you do not hear many irritating sounds while receiving CW signals. It is possible to tune in smaller steps when you do use the clock signal of Q14. But stabilization is less good then. Cx has also to be increased to 100 uF and Rx has a value between 68 and 120 ohm. But these values can be totally different in your circuit!
The first experiments were not a success. The solution was simple, I had chosen the wrong values for Cx and Rx, and that was the reason why the frequency control did not work.



The lock indicator with two leds.
Adjust the potentiometer so that they are equal in brightness.
Then the stabilizer is in the centre of the control range.

How to use the frequency stabilizer

When S1 is in the "open" position, the potentiometer acts as a fine tuning for CW and SSB. In the closed position, the VFO synchronizes on multiples of 976 Hz. With the potentiometer, you can tune to the next multiple of 976 Hz and adjust the stabilizer in the centre of the control range by means of the two leds (turn slowly). In the centre of the control range, they have the same brightness. It is funny to see that the brightness of the leds changes when you do move your

hand towards the VFO coil. If you move your hand too fast, the VFO unlocks.
With a bad choice of Cx and Rx, the frequency stabilizer locks often (unwanted and bad) on multiples of subharmonics of the clock signal. When rotating the potentiometer slowly, the circuit has to stay locked when one of the leds is almost off and you should not hear too many irritating sounds when receiving CW signals.

A VCO without varicap
Usually we do use a varicap to control the VFO frequency. But we can do that without a varicap.
Fine tuning can be done by just varying the voltage of the base of the transistor T2 via a 1M resistor with a 10k ohm potentiometer. The tuning range is approximately 60 kHz and I cannot explain why, but it is almost equal on all bands!
This method of varying the frequency without using a varicap is used to control the VFO frequency by the frequency stabilizer!



Free frequency marker generator! Just touch a pin of the 74HC4060 with a screwdriver.

Free frequency marker generator
When you do touch pin 7 of the 74HC4060 with a screwdriver, you will hear a tone on multiples of 500 kHz. Perfect for tuning to 7, 10 and 14 MHz.
Touch pin 4 with the screwdriver and you will hear a tone on multiples of 125 kHz. This can be useful when tuning to 10125 kHz and 14125 kHz.
And touching pin 6 is all you have to do to have a signal for tuning to 14062.5 kHz. Tune a little lower and you will receive the QRP signals on 14060 kHz.
And tuning to 7030 kHz can be done by touching pin 14.
You can adjust the 8 MHz oscillator exactly by changing the values of the 47pF capacitors.

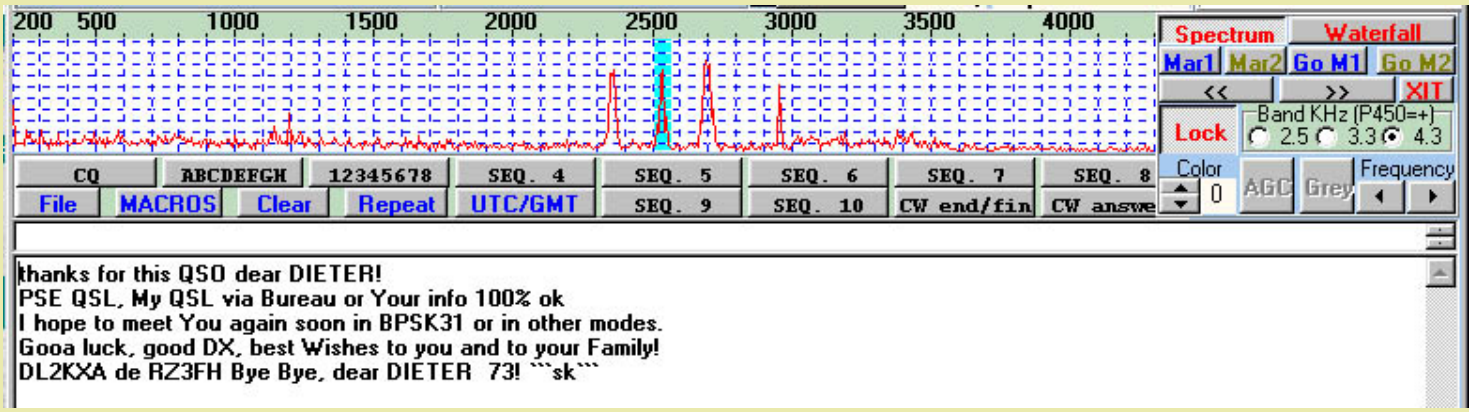


When the receiver is connected to the soundcard of the PC, you do not need the final LF stage of the original receiver (right side of the blue line).

Connection to the soundcard of the PC for PSK31 reception
The signal of the 1st LF stage can be connected to the microphone input of the soundcard. Switch on the microphone preamplifier of the soundcard. The second LF stage for the headphones of the original receiver is not required anymore.
The audio range goes to approximately 3 kHz. You can increase it for experiments with DRM or certain SDR programs.
Replace the 47nF capacitor by 4700pF and the 10nF at the collector of T3 by 1000pF.

Results

With the frequency stabilizer, PSK31 reception is good. With the lock indicator (the 2 leds), you can check if the stabilizer is within the control range. For reception of SSB and CW, the frequency stabilizer is switched off. The frequency steps are too large for SSB and CW and the stabilizer causes still some weak but irritating audio sounds. But the VFO is stable enough for the reception of CW and SSB. The fine tuning works perfect, tuning to SSB stations is very easy.



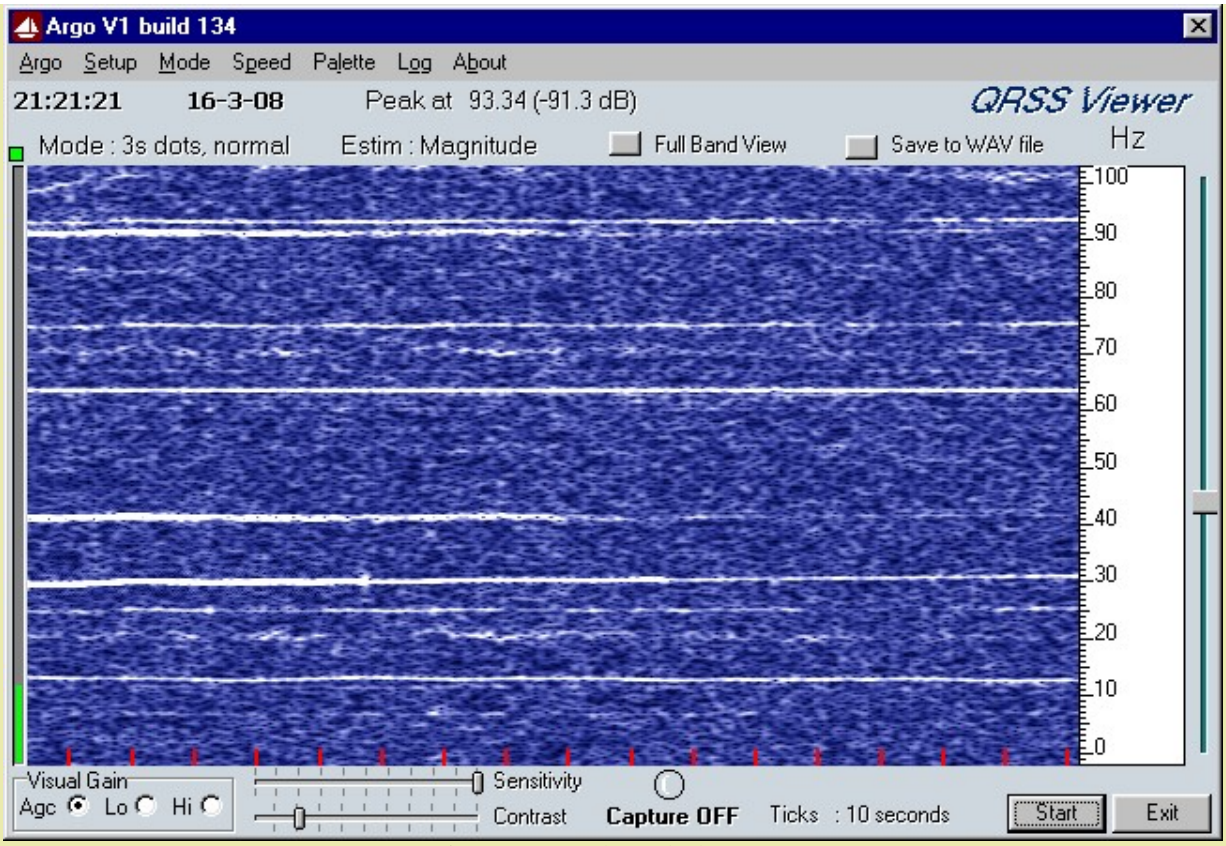
Reception of PSK31 with the MultiPSK program of
Patrick F6CTE goes excellent with the frequency stabilizer!

QRP beacons

Already on the first evening after adding the 30 meter band to the original 20 / 40 meter band version, it turned out that the receiver is not so bad: The QRP beacon SK6RUD on 10133 kHz (0.5 watt!) could be received. Not so very strong, but all information, including the link to the website www.radiorud.se was heard!
Also the 2 watt beacon of IK3NWK on 10140.8 kHz is often heard.

ARGO, a program for the reception of QRSS beacons with very low power

To make a QSO with very low power, that must be very interesting for us, QRP'ers! A few radio amateurs are active with transmissions with very low power, less than 100 mW. And they do make QSO's with all continents with such low power! That is possible by using a very low CW speed in combination with a special computer program such as ARGO. The CW speed is very low, 1 dot lasts 1 to 3 seconds. The frequency stability of the transmitter and receiver has to be very good. But this simple receiver with frequency stabilizer is certainly very stable!
Unfortunately, there were no active stations. But I could use a professional RF generator to test how much better such a QRSS signal can be received compared to normal CW signals.



Reception of QRSS signals with the ARGO program.
The 31Hz line is the weak testsignal.

And the results were indeed amazingly! The testsignal of the RF generator is the white line at 31 Hz. All other lines are interference signals of the PC or other signals that could be received with disconnected antenna The left part of the 31 Hz line is very bright, but was already so weak, that only slowly transmitted CW signals could be decoded by ear. The center part is 10 dB lower, inaudible but perfectly visible. The right part was even 20 dB weaker than slowly transmitted morse that just can be decoded by ear. Conclusion: A 50mW QRSS signal can do the same as a 5W QRP transmitter with 100x more power!

It is very nice to play with this program. I made a connection for a frequency counter at the frequency stabilizer, so that it is possible to measure exactly the reception frequency. Also the souncard has to be calibrated. My card had an error of approximately 20 Hz at 1 kHz. For the calibration, you can use the 976 Hz clocksignal. Touch this signal with you finger and you will see it on your ARGO screen.

And again we had much fun with a very simple radio circuit!

BACK TO INDEX PA2OHH

SWR METER FOR QRP USE

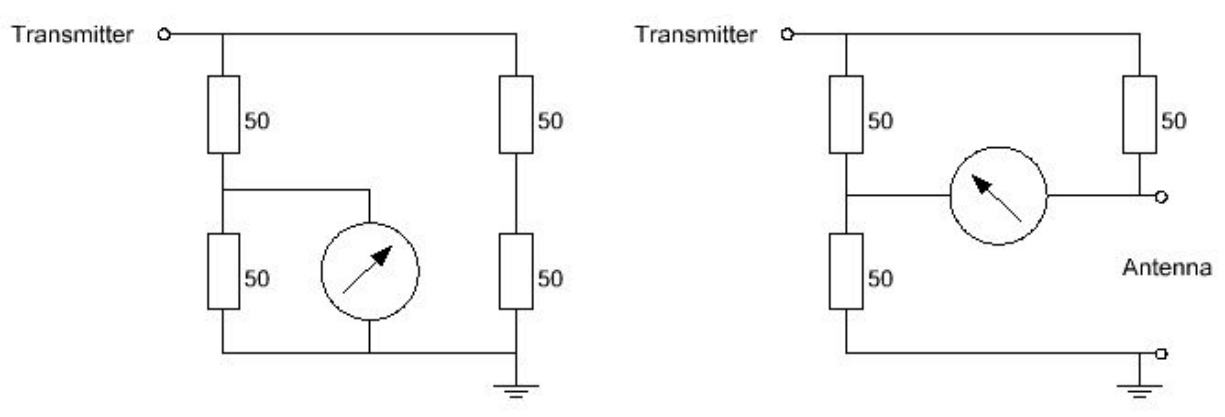
(2001)

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SWR meters for QRP portable use.

SWR meter for QRP use!
My SWR meter needed quite a lot of power to measure the SWR, especially on 80 meters. That was no problem in the shack, there is always a transceiver that can generate this power. But I needed to have a SWR meter that I could take with me while working portable in nature with an extendable dipole. It had to be robust and to be possible to measure the SWR with QRP power. I made two versions. One with a moving coil meter indication and one with a LED indicator. The moving coil meter was better but less robust than the version with the LED. This type of SWR meter has a number of advantages. During the measurement, the load of the output stage is at least 33 ohms and maximal 100 ohms. Therefore, the transmitter output stage cannot be damaged by extreme mismatches. And you can also use the meter as a dummy load. During the measurement, the emitted power is only 25% of the normal transmit power. If you want to experiment with a quarter of the transmit power during working QRP, then you put the meter in measurement mode SWR + REF.



Left the principle of the forward measurement, right the principle of the reflected measurement.

operating principle
The measurement is based on the Wheatstone bridge. At the left you can see the principle of the forward measurement or

the calibration mode. During this measurement, the antenna is replaced by a resistor of 50 ohms. The power is measured across one of the resistors and the meter is set to full scale. At the right you can see the principle of the reflected measurement. The resistor of 50 ohms of the bridge is now replaced by the antenna. When the antenna is exactly 50 ohms, there will be no voltage present across the meter, as the bridge is in equilibrium.

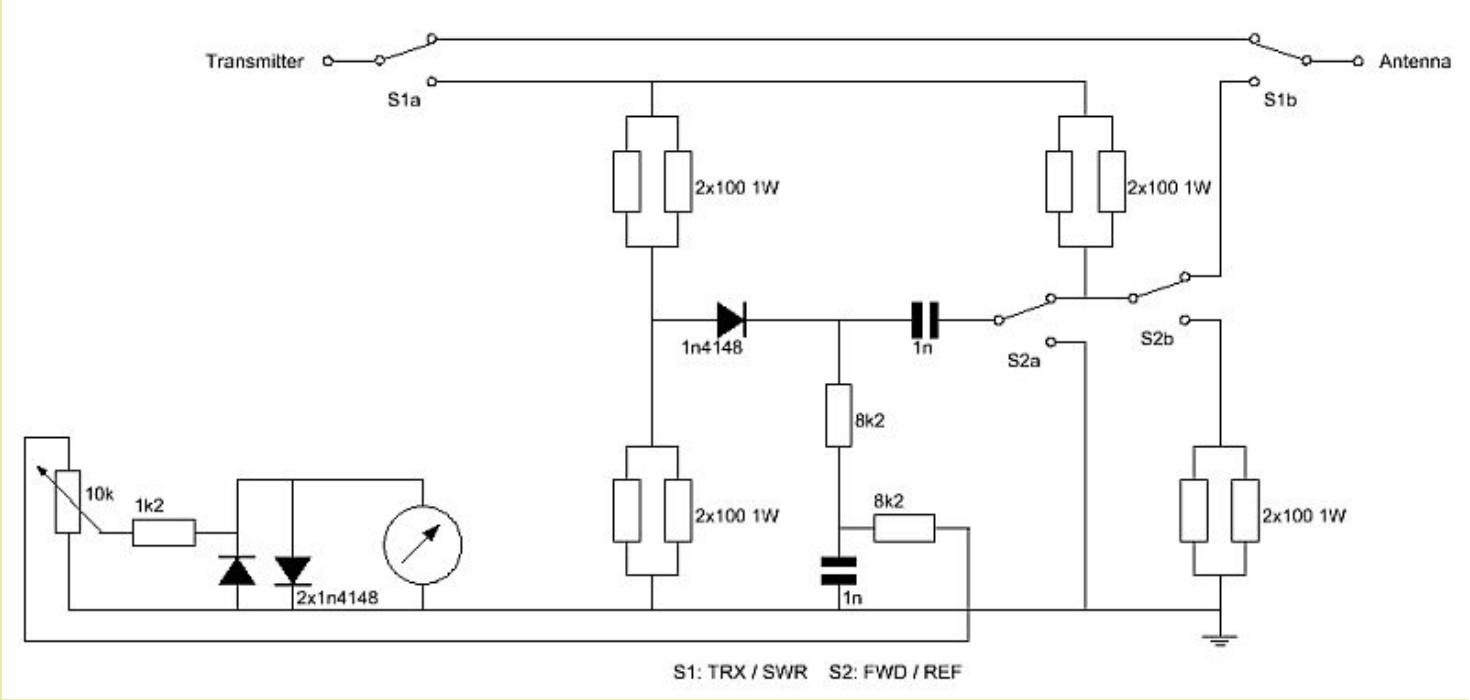
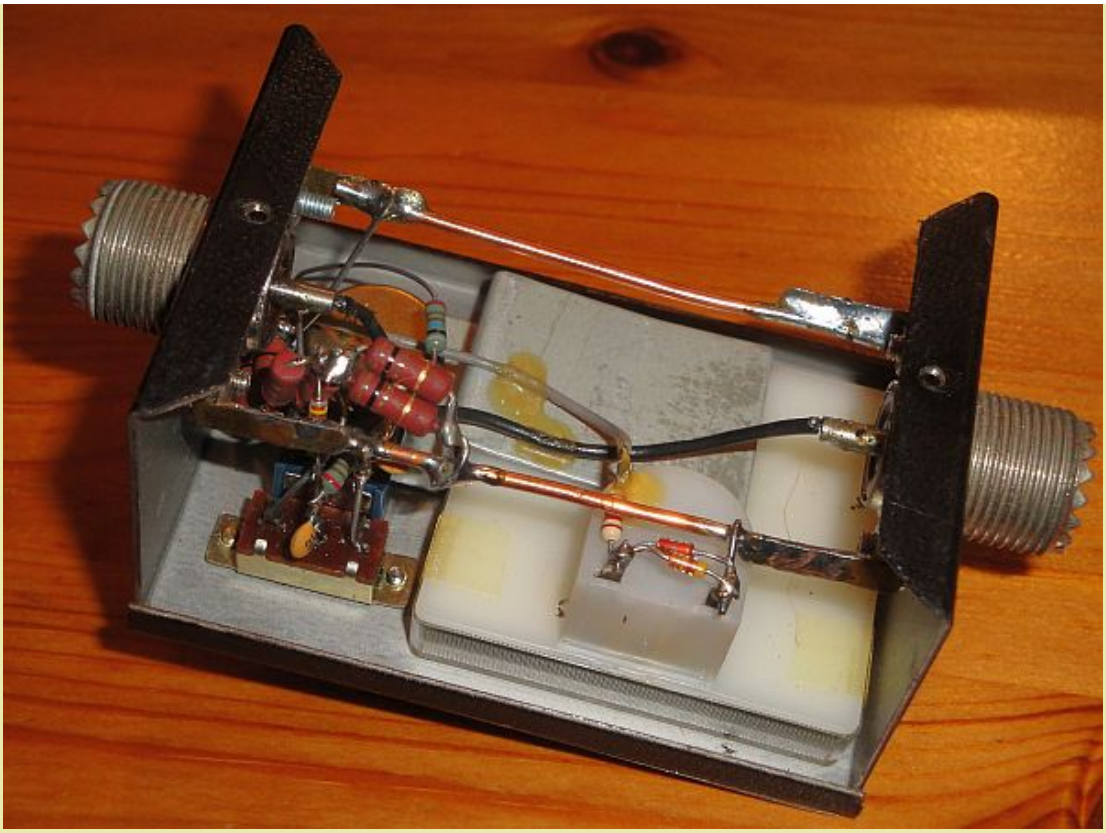
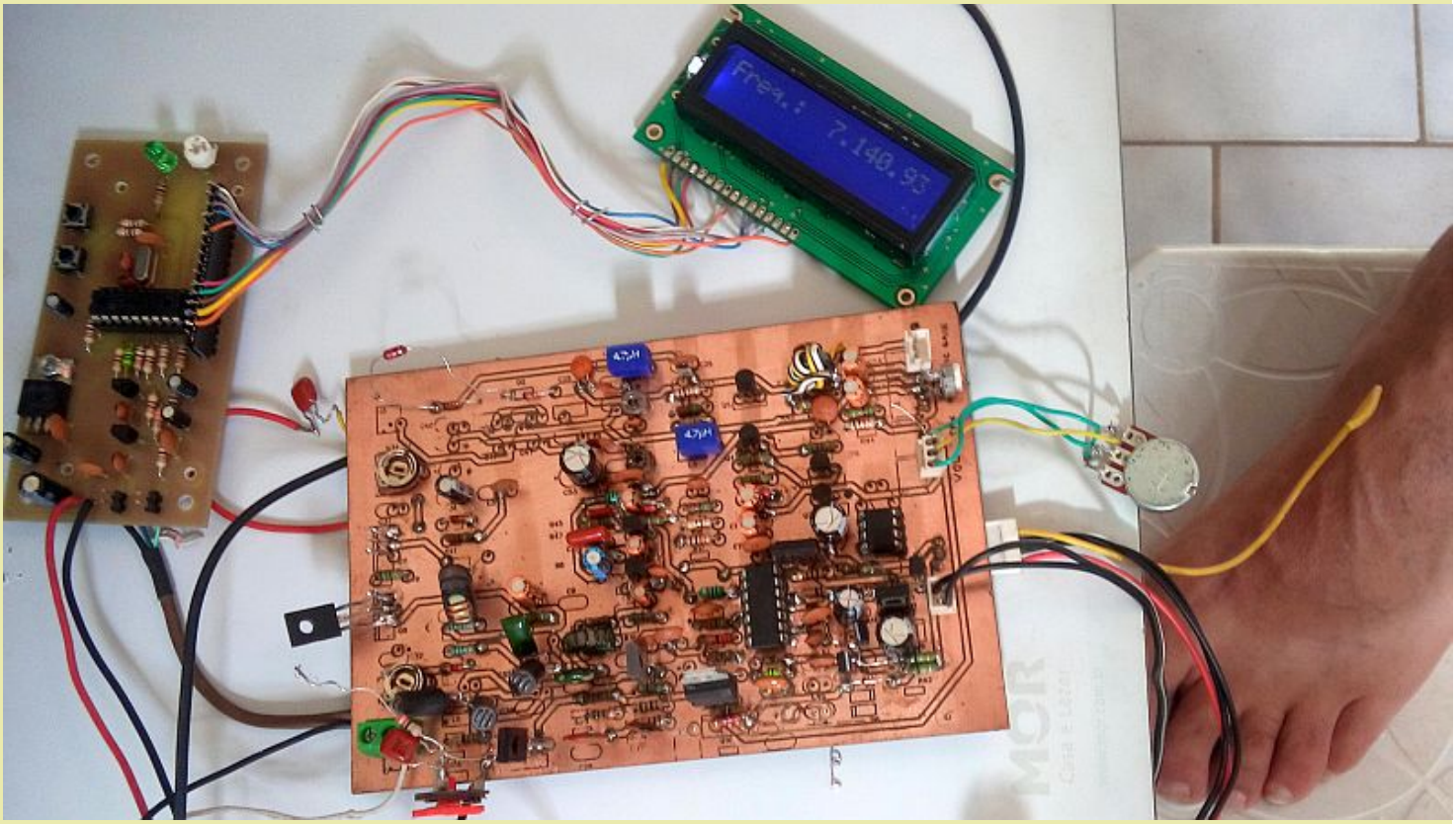


Diagram of the SWR meter with a moving coil meter as an indication.
big diagram

Description
At a flea market a SWR meter for the 27 MHz band was bought. It was in good condition and so I had already the connectors, meter with scale and control knob. Only the switch S1 had to be built-in, just above the existing switch S2. All the original components have been removed and replaced by new components as given in the diagram.
During transmission, the switch S1 is in the position TRX and the bridge is not used. When adjusting the antenna, S1 is set to the position SWR. When the switch S2 is in the shown position REF, the RF voltage is measured between the two halves of the bridge. When the antenna impedance is exactly 50 ohms, the measured voltage is zero. When we set the switch S2 in the FWD position, the RF voltage across the 50 ohm resistance at the bottom left is measured. The switch S2b replaces the antenna by a resistor of 50 ohms. The resistor of 50 ohms of the bridge were made by two resistors of 100 ohms - 1 watt in parallel. So the bridge can dissipate 8 watts, enough for our QRP transmitters.
After the diode detector you can find a 8k2 ohm resistor and a capacitor of 1 nF. This is a low pass filter for filtering out the RF component. The subsequent 8k2 resistor does reduce the control range of the potentiometer. By means of the 10k potentiometer, the meter is adjusted to full scale in the FWD position. The two diodes in parallel with the meter limit the voltage across the meter up to ą 0.6 volts, and are intended to protect the meter against too large peaks. One of the two diodes is unnecessary, as we do use only positive voltages.



The inside.



A nice Barefoot Power DSB transceiver for 40 meters, the Uirapuru made by Andre.
See the website of PY2OHH (http://py2ohh.w2c.com.br/trx/uirapuru/uirapuru.htm)



The second version with a LED as indicator.

The second version with a LED as indicator.
But such a meter with a needle is a fragile thing. Therefore, a second version has been made with a LED as an indication. A real decent thing! But not as accurate as a moving-coil meter. And difficult to read in sunlight. But still a good thing to tune the extendable dipole.

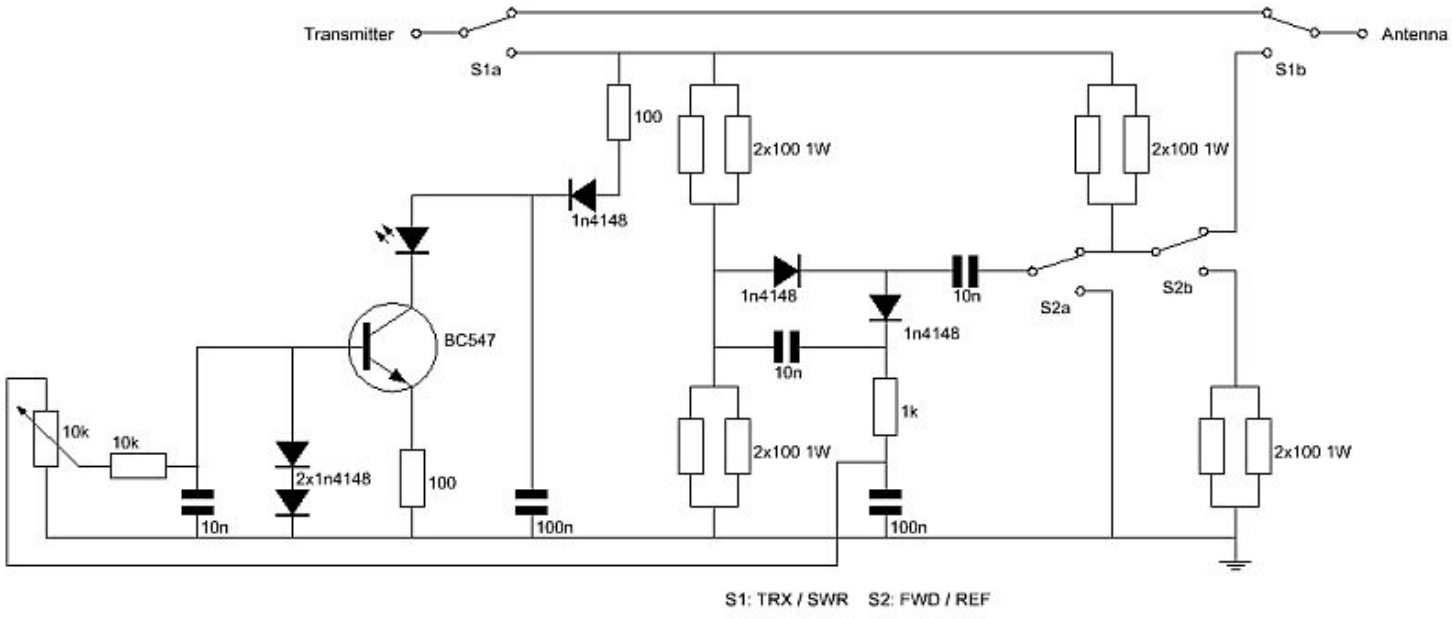


Diagram of the second version of the SWR meter with a LED as indicator.
big diagram

Description
The measuring bridge is the same as the version with the moving coil meter, see above.
For the diode detector, a slightly different circuit is applied, one that doubles the voltage, as for the LED a little more voltage was desirable. After the diode detector you can see a resistor of 1k ohm and a capacitor of 100 nF. This is a low pass filter for filtering out the RF component. Then follows the potentiometer and the 10k resistor with 10nF capacitor

ensures that the transistor and diodes will not detect RF. The two series-connected diodes 1N4148 to the base of the transistor ensure that the voltage on the base is limited to ą1.4 volts. The base-emitter voltage is 0.7 volts. Thus the voltage across the emitter resistor of 100 ohm is maximal 0.7 volt and maximal 7 mA can flow through the LED. With the 10k potentiometer and in the FWD powition, the meter is adjusted so that the LED hardly increases in brightness. That is the mentioned 1.4 volt point. Read the power on the indication of the potentiometer and you know approximately the transmit power of your QRP transmitter. The transistor circuit is supplied from the rectified voltage of the RF transmitter. The applied LED needed a lot of current. Newer LEDs do need much less current, so you can choose a higher value for the 100 ohm emitter resistor (560 ohms or so).



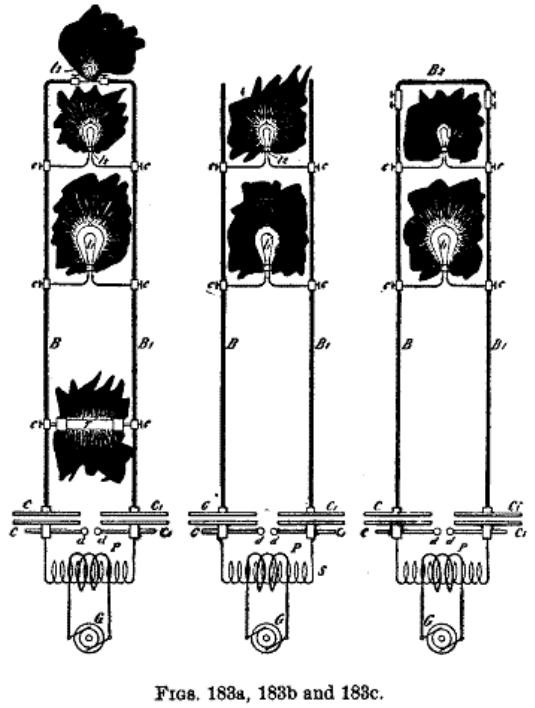
The inside. Glue, solder, no printed circuit board.

The extendable dipole antenna

An extendable binary dipole was made. There were pieces of wire of 10cm, 20cm, 40cm, 80cm, 160cm, 320cm and 640cm for each dipole leg. By connecting the desired wire lengths, you can tune the antenna to any desired shortwave frequency. The wire ran through tabs in a nylon wire high in the air. The end was attached with a plastic clip to the nylon wire. It worked, but the hassle with all of these wires in a plastic bag was not a success. So I did not use it anymore and made three dipole antennas, one per band, 40 meter, 30 meters and 20 meters. That worked better.

BACK TO INDEX PA2OHH

Tesla's Hairpin Circuit



FIGS. 183a, 183b and 183c.

Tesla's own schematics for the Hairpin Circuit

Introduction

Nikola Tesla, the first person to seriously study radiant energy more than a century ago, built a simple circuit to generate radiant energy so that its effects can be readily demonstrated. You **MUST** have a look at this as it goes against everything that we have been taught about electrical energy.





The Tesla Hairpin Circuit in action

Hairpin Circuit Demonstration Video

Karl Palsness has posted on his YouTube page two videos demonstrating the Tesla Hairpin Circuit in action. This clearly shows effects that cannot be explained using conventional physics/electricity:

- Tesla Radiant Energy video explaining and demonstrating the Tesla Hairpin Circuit
- Followup video showing a bulb in the water using radiant energy produced by the Tesla Hairpin Circuit

Lecture Given at the 2009 Alternate Energy Partnership Conference (AEPC 2009)

On May 30, 2009, Karl Palsness gave a lecture at the 2009 Alternate Energy Partnership Conference held in Waldorf, Maryland. This lecture blew everyone away and brought the house down!!!

It has been graciously posted on YouTube in 10 parts thanks to Spodie Odie:

- Part 1 - Part 2 - Part 3 - Part 4 - Part 5 - Part 6 - Part 7 - Part 8 - Part 9 - Part 10

Some Articles by Nikola Tesla Related to the Hairpin Circuit

- ***Experiments With Alternate Currents of Very High Frequency and Their Application to Methods of Artificial Illumination*** - PDF version, Word version

  Lecture delivered before the American Institute of Electrical Engineers, Columbia College, N.Y., May 20, 1891.

  Note: This first lecture does not talk per say about the hairpin circuit but gives important background information that should be read before moving on to the next article.

  As most versions of this lecture out on the internet contain many typos and even errors, I have proofread it and made many corrections based on the printed version of the lecture found in *Lectures, Patents, Articles* published by the Nikola Tesla Museum in 1956.

- ***Experiments with Alternate Currents of High Potential and High Frequency***

  Lecture delivered before the Institution of Electrical Engineers, London, February 1892.

  Note: This second lecture also does not talk about the hairpin circuit but gives important background information.

- ***On Light and Other High Frequency Phenomena***

  Lectures delivered at the Franklin Institute, Philadelphia, February 1893, and National Electric Light Association, St. Louis, March 1893.

Discussion Forums

There are some discussion threads where the Hairpin Circuit is being discussed. It is a great place to get your questions answered or gain additional insights:

- http://www.energeticforum.com/renewable-energy/3467-teslas-stout-copper-bars-hairpin-circuit.html

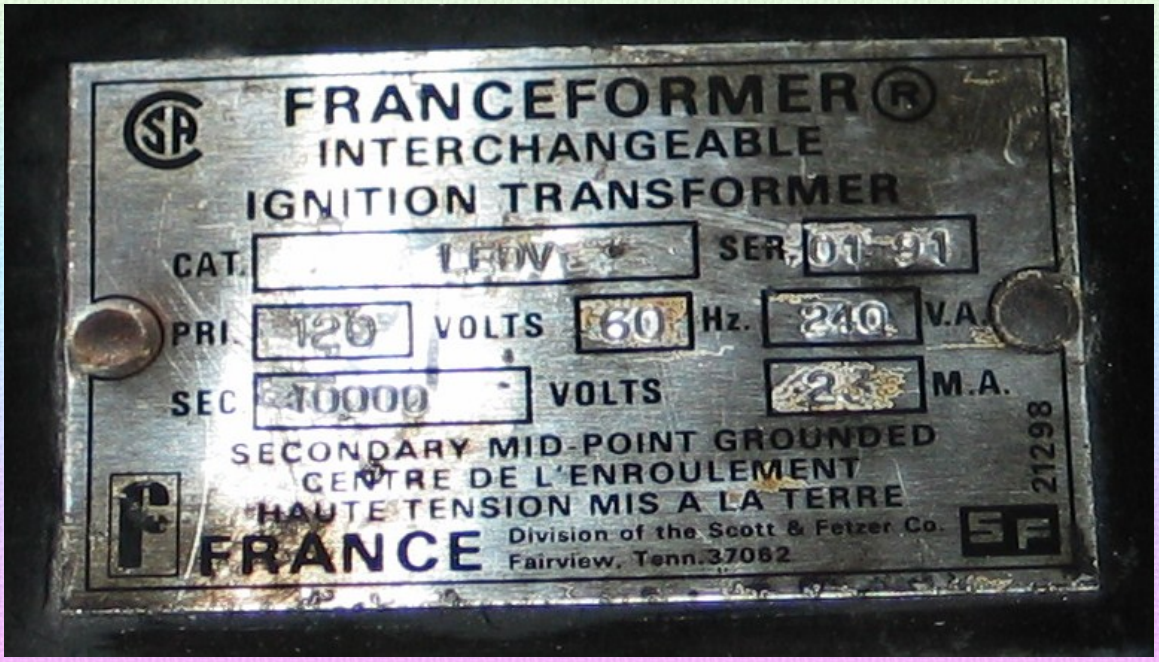
Close-up Pictures of the Hairpin Circuit Replication

For those who are curious to see close up pictures of Karl Palsness' Hairpin Circuit replication used in the videos, here are close-up pictures. For most of the images, if you want a higher-resolution version, just click on the picture.

10,000V AC Transformer

In the demo, a 10,000V AC, 23 M.A. furnace ignition transformer is used.

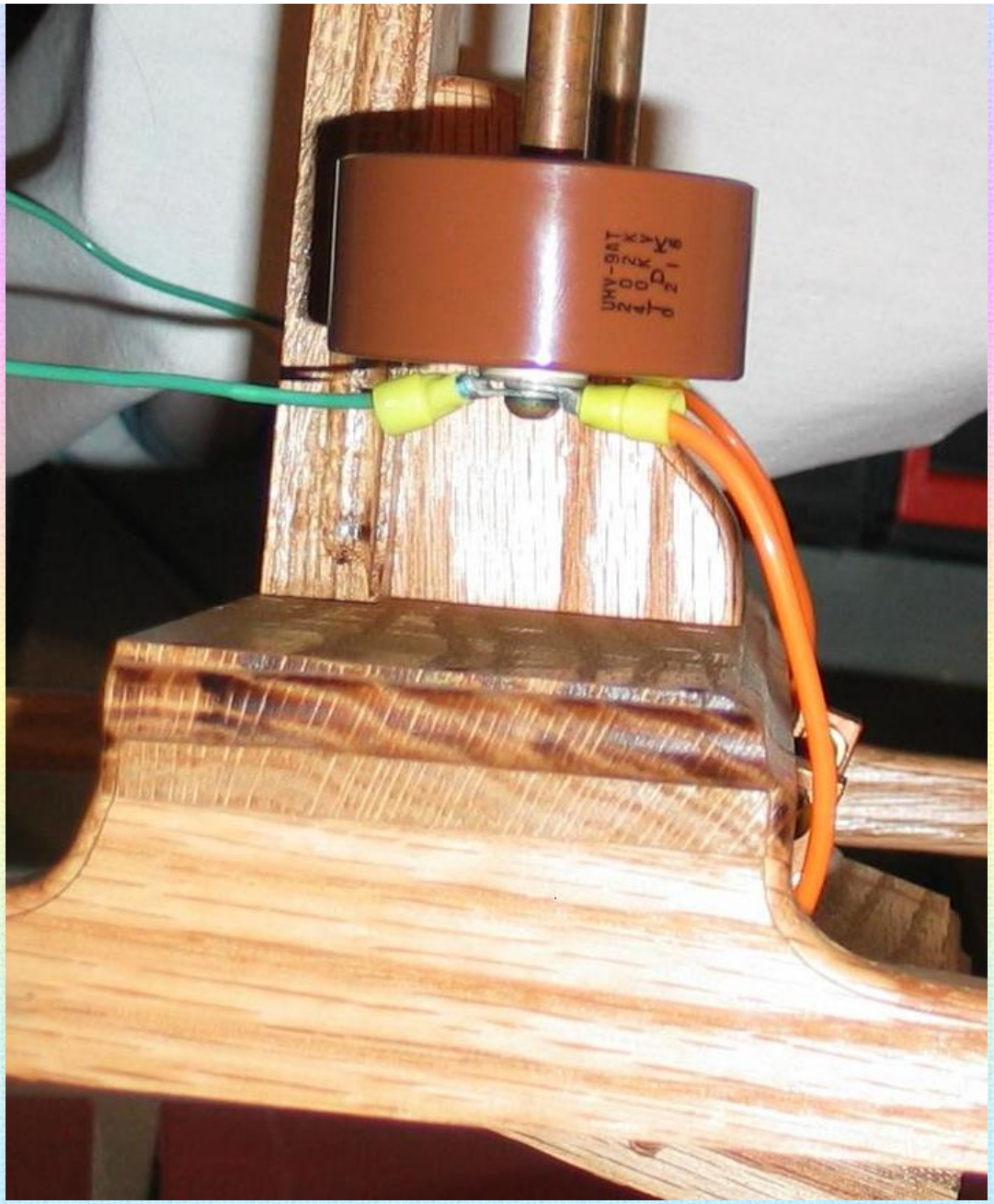




Hookup

Each pole of the 10,000V AC transformer is hooked up to the bottom of one of the capacitors (green wires) which then also hooks up to each side of the spark gap (orange wires)



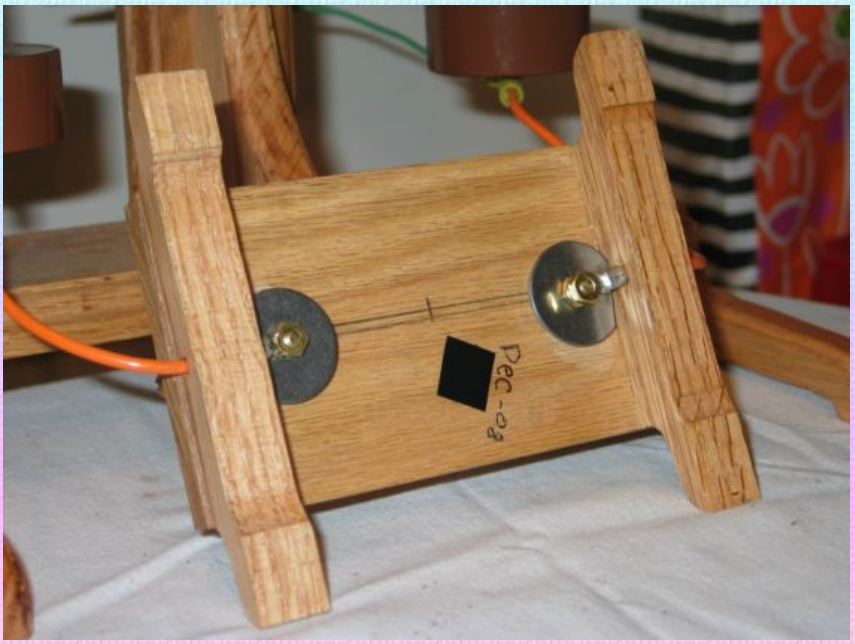


Connection of the wires to the TDK High Voltage Ceramic Strontium Titanate Doorknob Capacitors (High Current / Quick discharge) 40KV, 2000 pF - (2 1/4" x 1 1/4" high)

Spark Gap

The spark gap electrodes are comprised of carbon welding rods mounted on two screws so that the distance between the electrodes can be easily varied.





Stand

The two 3/8"x48' copper rods are held in place by supports on the wooden stand. If you notice, they can easily be removed so that the copper rod can be easily changed and/or permit the removal of the sliders.



Disclaimer/Warning:

If you decide to replicate this circuit, use extreme care. Improper experimentation with high voltages can kill you! When you see Karl and others touch the Hairpin Circuit or bulbs, it is a part of the circuit where radiant energy is present but where there is NO conventional electricity present.

The way the circuit is constructed, the top part above the capacitors contains radiant energy only. Below the capacitors, it is regular 10,000 volts AC which can cause serious injury and even death.

Do not attempt to replicate this at home unless you have a good understanding of high voltage currents and how Tesla designed the circuit. Also, do not run the circuit using low voltages as the behaviour is different.

Last modified: October 8, 2016

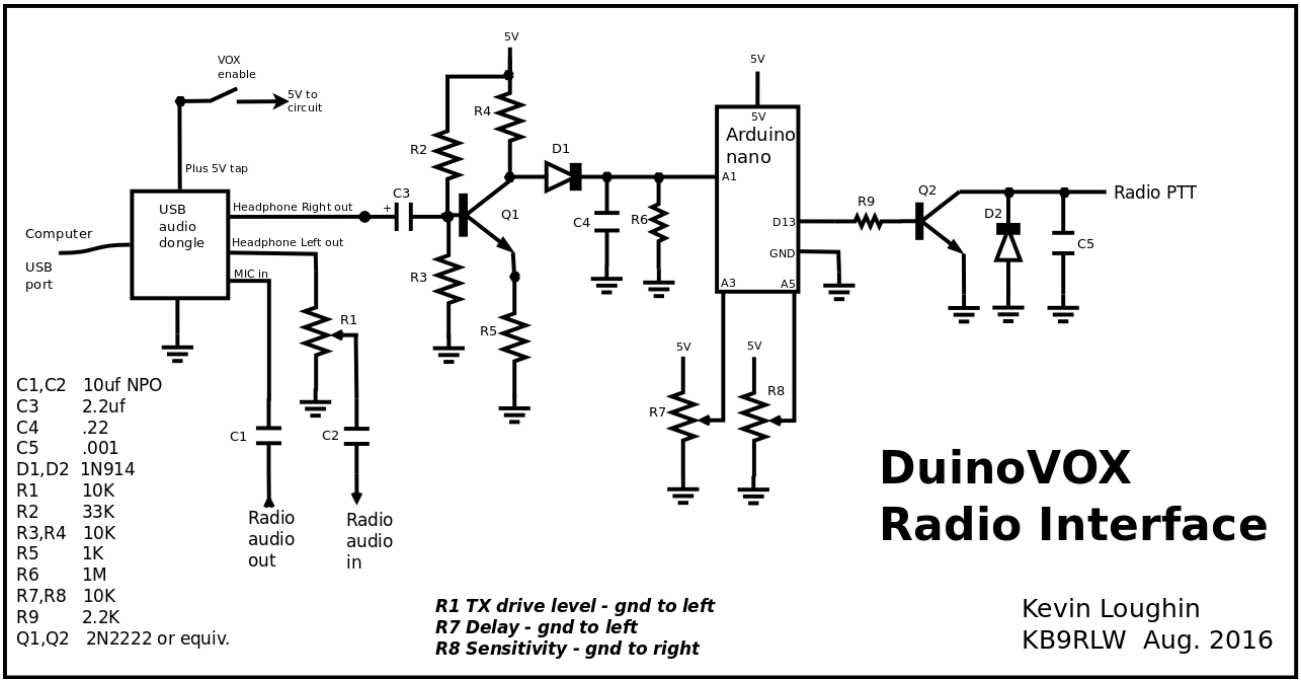
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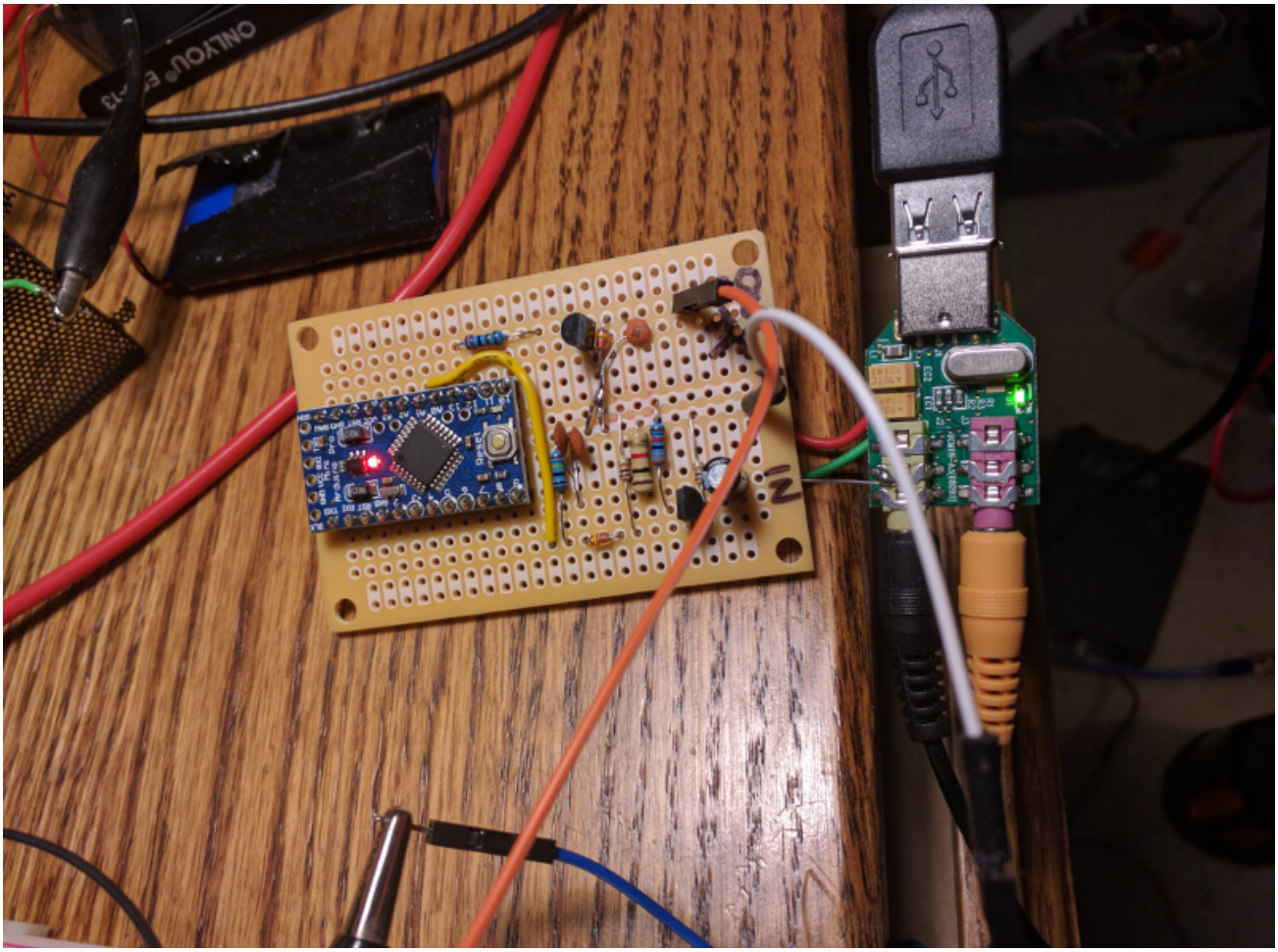
stuff that i do and things that i make

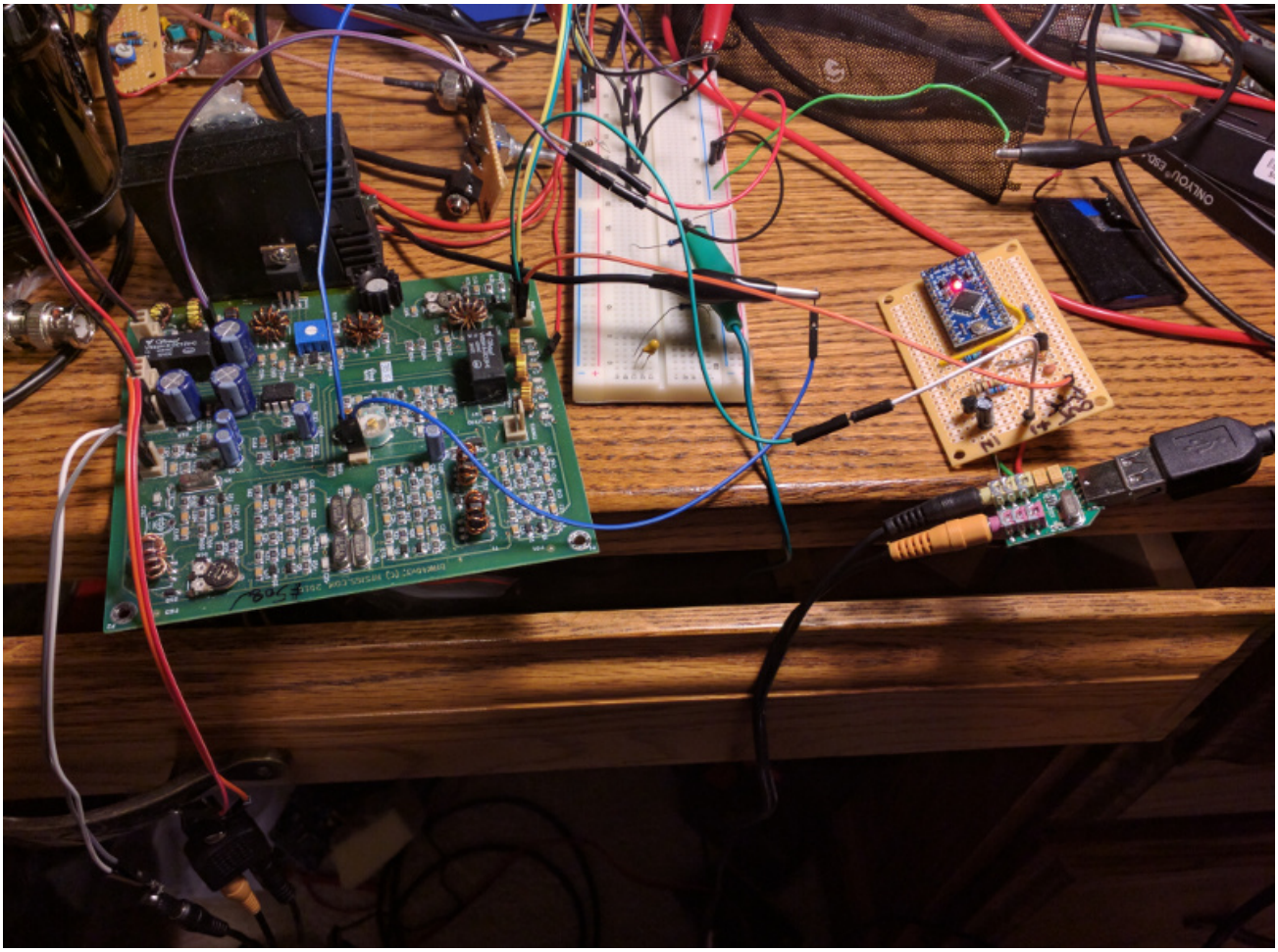
vox interface – more ft8

PUBLISHED AUGUST 14, 2017

I finally got an ft8 qso with the bench top bitx. The first few times I tried, including in my last ft8 post, I was manually engaging the ptt with a push button. That got old fast, so I found a vox ptt interface that I could replicate with parts I had on hand. The DuinoVOX is a homebrew device that replicates the features of the Signalink interface. I slapped my own version together this weekend with this usb sound card and an arduino pro mini.







It works great. I need to put it in an enclosure and add the potentiometers to get the full functionality.

PUBLISHED IN **CIRCUITS**, **ELECTRONICS** AND **RADIO**

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scrolling one line on a 16×2 lcd

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usb sound card/vox interface for digital modes – awsh.org

[…] I finally finished my usb sound card/vox interface. The original post with the schematic is here. […]

OCTOBER 16, 2017 | REPLY

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Description

The MK484 is a AM radio receiver IC which has automatic gain and up to 72 db gain. It is cased in a TO-92 Case that looks like a transistor. The MK-484 runs on 1.1 to 1.8 volts so a single 1 1/2 volt battery will work. The MK484 needs very few external parts to build an AM radio. The MK-484 needs a tuning Capacitor and Ferrite Rod Coil or also known as a loopstick antenna we sell both items.

Yes a real MK484, not like other sites that sell MK484/TA7642. If you see this designation on other sites you are getting a TA7642 not a MK484.

The YS414, TA7642, UTC7642, CD7642 and KM484 are the same as the MK484 only different manufactures.

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